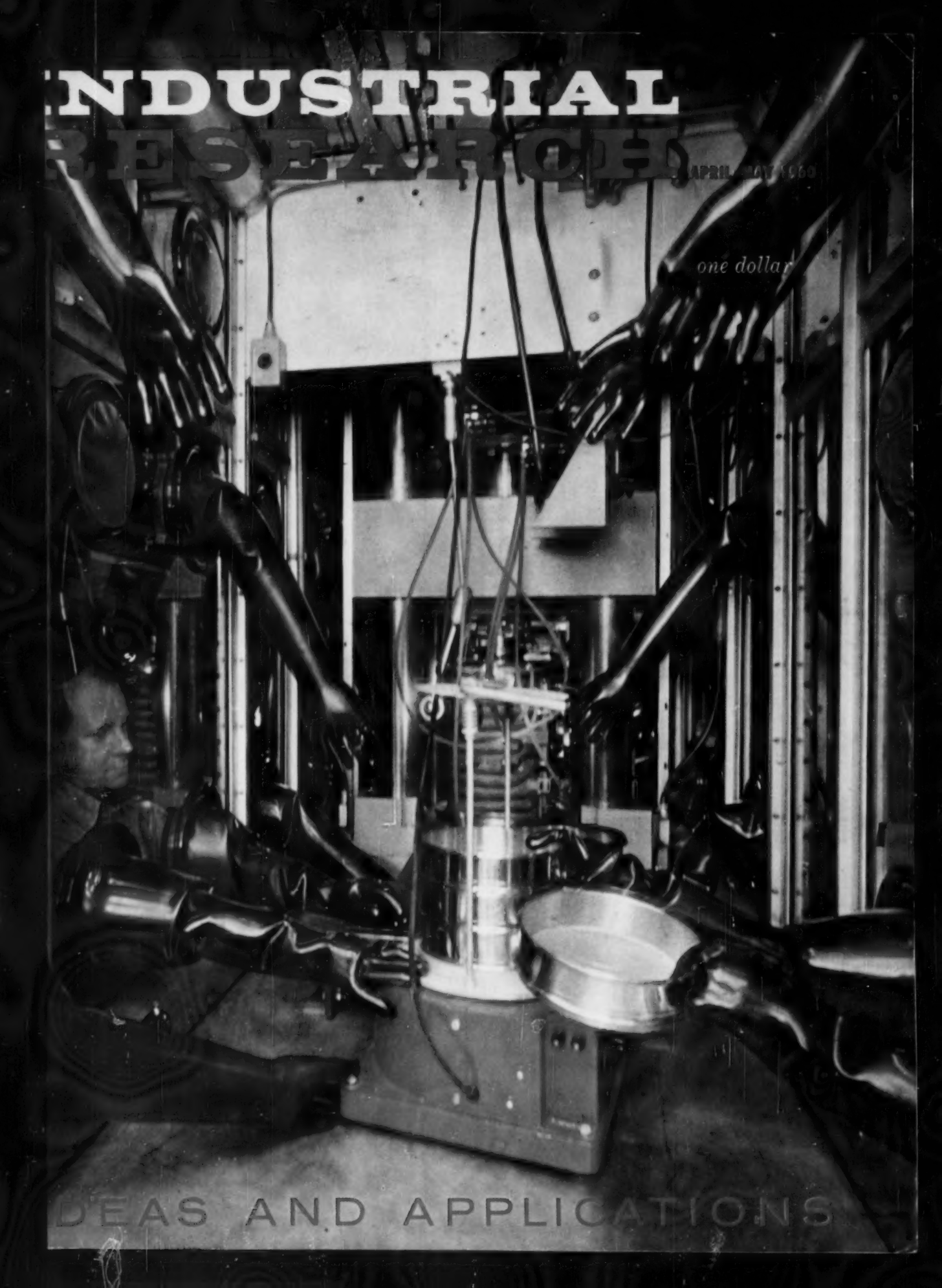
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I•R photographer Jon Pownall took the photo (see below) by getting inside the chamber prior to the first insertion of plutonium.

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Plutonium metallurgy is one of many Argonne programs described in the I•R picture portfolio beginning on page 37.

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APR-MAY 1960

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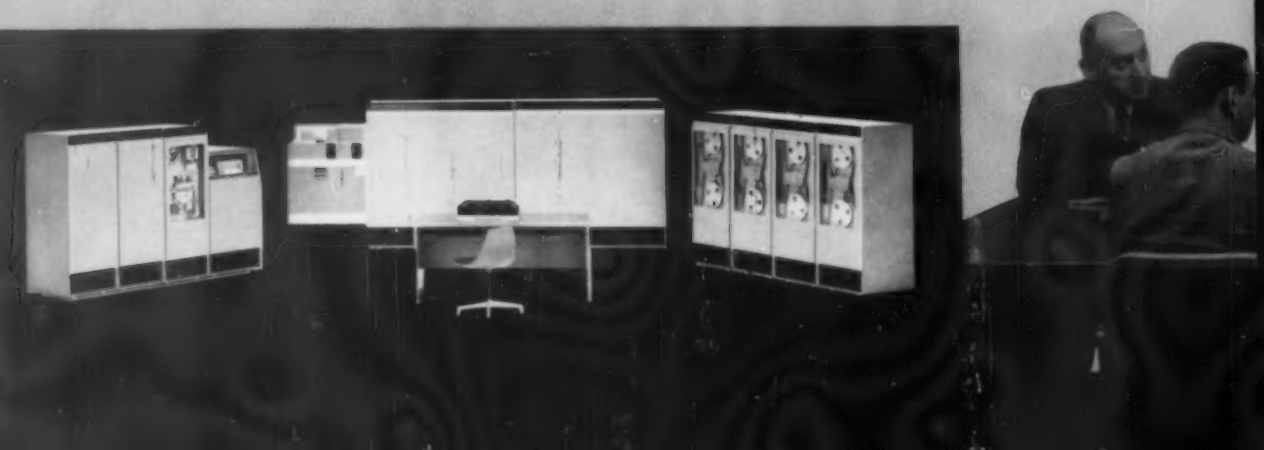

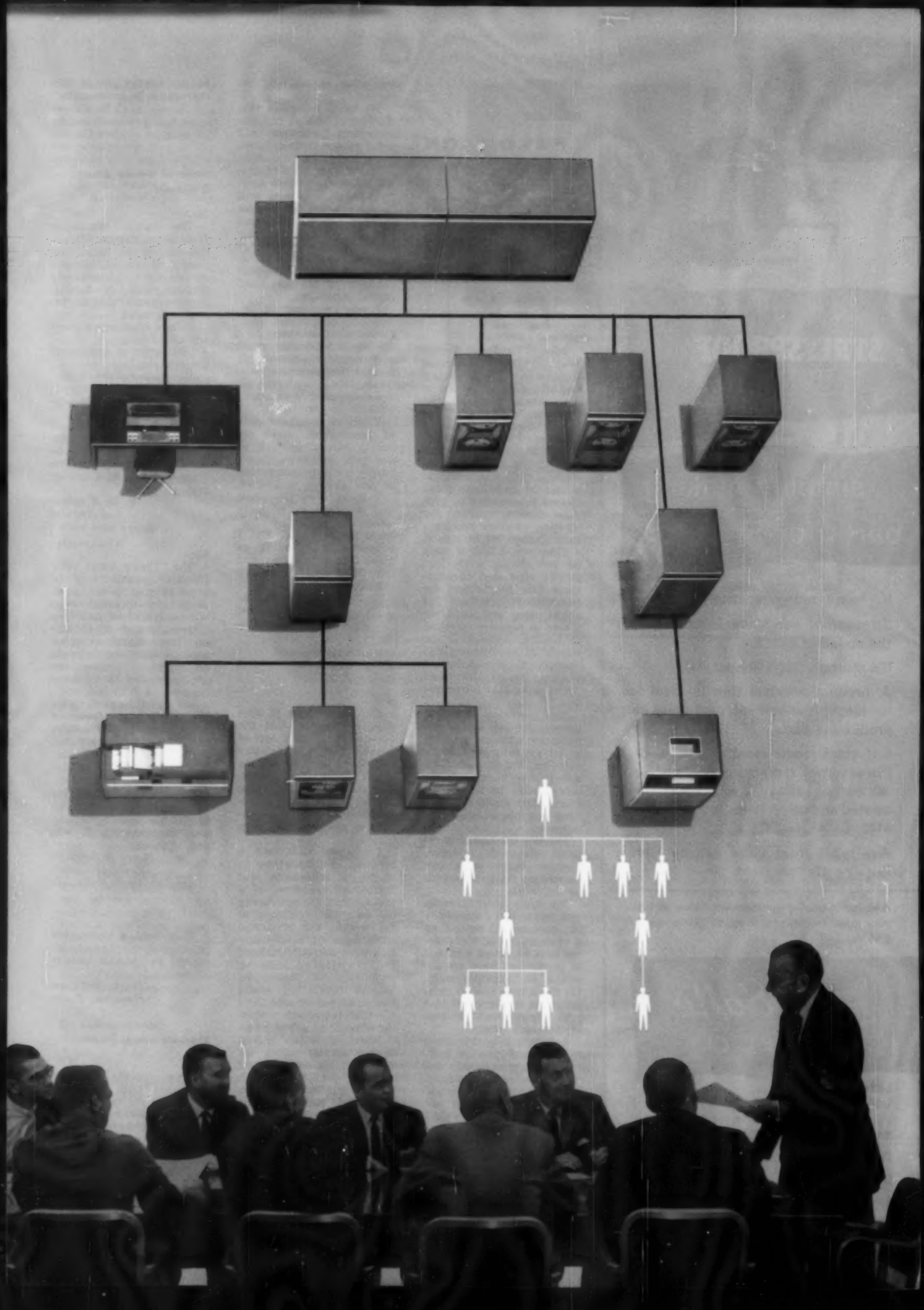

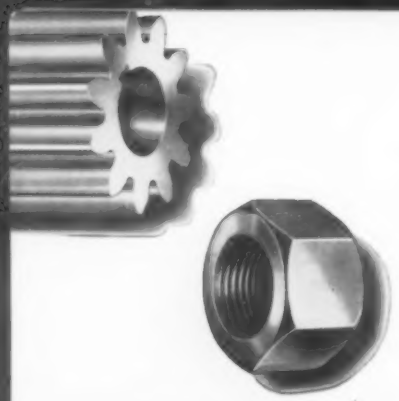

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IR FEEDBACK

The automation controversy

Sir:

I found Dr. James Stern's article, "The Automation Controversy" interesting and stimulating, and am in enthusiastic agreement that the term "automation" has been abused almost out of meaning. I am also in accord that more and better research on the economic, social, and psychological effects of technological change are needed to provide sensible guides for meeting whatever problems such change might create.

However, I find it hard to go along with Dr. Stern's view that management first proclaimed the revolutionary virtues of automation, and later, in a kind of negative response to unions, deprecated the effects of technological change, to the point of creating an atmosphere "which stifled investigation."

The potential for systematic inquiry in the behavioral sciences possibly is not yet fully realized by industry, but it should be noted that many of the case studies to which Dr. Stern refers would not have been possible without such support.

Pending the complete returns on such research, however, a few things can be said on the subject with confidence:

We know, for example, that while the controversy has gone on for more than a century, up to the present time improved methods of production have not resulted in unemployment. On the contrary, with technological development at a peak, employment is also at new high levels.

I do not deny that there will be problems of individual displacements and transitional unemployment. It is much easier, though, to identify jobs that are being lost to technological changes than it is to see those that are being created. On the other hand, the mechanisms we have for effecting transfers of employes from the one to the other are at best imperfect.

We must recognize that the rate of change and displacement problems will differ greatly from industry to industry. For example, I believe that such change will occur much more slowly in the steel industry with its tremendous investment in large capital equipment of long life and the relative stability of its product than in industries in which there are frequent product changes of smaller fixed capital structures.

I was interested in Dr. Stern's comment that "Within a few years . . . the steel producing areas of Pennsylvania could well *become* (my emphasis) distressed areas with *chronic* unemployment in excess of 10%."

While an infinite variety of possibilities could occur, a careful analysis of the steel industry's future hardly warrants acceptance of this gloomy possibility.

I agree with Dr. Stern that automation properly introduced presents a challenge to all of us. But I believe that it offers us great opportunities and only incidentally secondary problems.

William G. Caples
Vice-President
Inland Steel Co.

Sir:

Dr. Stern seems to start with the notion that the country needs some sort of grand plan relating to automation or else we will be in for nothing but trouble. His main emphasis is in deploring that lack of information makes it impossible to put the grand plan together.

I disagree with such a premise. Automation is simply a refinement and further advancement of a process that has been going on since the invention of the wheel. The economic advantages of mechanization were not only realized but translated into an abundance for people the like of which the world had never before seen. And all this happened despite the absence of grand plans.

Man simply has proven he has greater ability for acting in his own interest than he is credited with by the theoreticians who urge that others do his thinking and planning for him.

Given the record of the past, why now in 1960 must we become alarmed over the capacity of the American people to adapt to the advantages of further gains in productivity?

C. H. Thayer
Vice-President
Sun Oil Co.

Throw away your clothes

Sir:

The recent interesting feature on disposable fabrics called to mind the image of an unfortunate maiden who, probably through lack of timing, became immortal in the famaliar limerick:

"There once was a maid from St. Paul,
Who wore a newspaper dress to the ball.
Her dress caught on fire,
And burned her entire
Front page, sports section, and all."

Perhaps the author of your article can assure future potential consumers of disposable fabrics freedom from concerns of a similar fate.

R. D. Weglein
Los Angeles

Sir:

The "Throw Away Your Clothes" article was of great interest to me, especially the spray-on nonwovens tried by Cambridge University and A. D. Little. The area shows some promise with reference to an improved product we are interested in developing.

George E. Gross
President
Future Products Research Inc.

Sir:

Your Feb-March cover of a nude, illustrating the disposable clothing article, was disappointing. It was out of focus.

Harry A. Sutcliffe
Research Center
Assn. of Amer. Railroads

Sir:

You need a new color photographer. The cover on the Feb-March issue is all blurry.

D. A. Williams
Houston, Texas

Penetrating rays

Sir:

Your report on "The Industrial Uses of Penetrating Rays" has omitted any reference to equipment which we either manufacture or represent here in the U.S. Omitted were the Brown Boveri 31-mev betatron, Fedrex x-ray equipment, and our own unique

"puff camera" for handling iridium[192] and cobalt[60].

Your front cover was most refreshing and would seem to apply equally well to penetrating rays as disposable clothing.

Bruce W. Smith
Nondestructive Testing
Curtiss-Wright Corp.

Sir:

The x-ray article is interesting and well-written, but unfortunately is much too limited as it omits two extremely important industrial uses — x-ray fluorescence and x-ray diffraction.

Mr. Berland has apparently heard of these, but has decided either that he doesn't understand them or that they are not important. They are *very* important; perhaps $10-million worth of equipment is sold annually for these two uses.

I. Fankuchen
Head, Applied Physics Div.
Polytechnic Institute of Brooklyn

The I•R 1960 forecast

Sir:

Under the topic of "aircraft and missiles," you state that Electro-Optical Systems is working on a joint effort with Rocketdyne in developing an ion-propulsion system for space vehicles.

I would like to emphasize that EOS is not working on any joint project whatsoever with Rocketdyne, but has been pursuing ion-propulsion system studies and development under prime government contracts for the past two years.

David T. Traitel
Electro-Optical Systems

Sir:

Aerojet has been plagued by casting difficulties for some years, along with the rest of the aircraft and missile industry. Thank you for publishing exactly what we needed to make an important point.

R. H. Patchen
Production Engineer
Aerojet-General Corp.

Overthrowing 'the airplane'

Sir:

The subject point of Mr. Wylie's article, "The Flying Machine: a New Era," is well taken. The new aircraft usually are whirlers rather than planers. And the new spacecraft, of course, are neither airships nor spaceplanes. It took 10 years to call flying machines airplanes. It may take another 10 years to call them flying machines again. But by then we may be teleporting and it won't make any difference.

B. A. Thompson
Aerodynamics Inc.

The I•R readership poll

Sir:

As editor of a company technical magazine, I was extremely interested in the unusually high response to your readership poll. Our own poll of a few years ago didn't have quite as fortunate a fate. Please send me the detailed analysis mentioned.

M. Harrington
Raytheon Co.

(A 10-page analysis of the questionnaire, in which 62% of I•R readers polled returned forms, is available on request.)

General feedback

Sir:

You have a magazine of which you can be proud. I read it regularly.

T. C. Wherry
Manager, Instrumentation & Automation Branch
Phillips Petroleum Co.

Sir:

I think very highly of your magazine and, in fact, have a personal subscription. It is seeking to fill a very important void and providing a meeting ground for our fractionated technology.

Warren E. Alberts
Vice-President
United Air Lines

Sir:

We were delighted to see that your fine magazine changed to bimonthly issues.

D. G. Williams
Development Engineer
P. R. Mallory & Co. Inc.

Sir:

Concerning your December issue cover of a missile exploding, I can honestly say I've never been more impressed by any other cover I've seen.

Richard Moss
Stevens Inst. of Tech.

Sir:

I became a subscriber to I•R through the complaints of science fiction editors, who say they have a hard time keeping up with your presentation of actual achievements and trends in research.

Victor L. Ricketts
Palo Alto, Calif.

Sir:

Your pioneering in the field of scientific and industrial accomplishments is a great achievement for intellectual strength of this country, and therefore I sincerely wish your successful continuation.

Nicholas P. Setchkin
Research Engineer
Nat. Bureau of Standards

Sir:

I was so impressed with the contents of your last issue, I would like to buy previous copies.

Harry C. Bertuccelli
Garden Grove, Calif.

Sir:

What American companies do not know about doing business in Asia is appalling. If I find the time I'd like to do an article on "How not to do business in underdeveloped countries."

Niels C. Beck
Director, Union of Burma Applied Research Inst.

Sir:

I am happy to find a magazine dealing with matters of a technical nature from the viewpoint of the philosophical details that must be subsumed if we are to understand where we are going. Most especially your articles on the automation controversy and executive inefficiency were quite revealing.

Hal Borgen
Lumen Inc.

Sir:

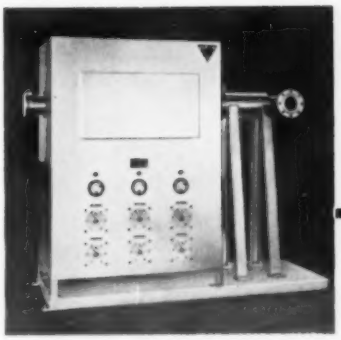
We take your journal here in the library and find it very useful.

Alfred E. Brown
Vice-President
Harris Research Laboratories

Sir:

Your article on "Organizing Research" was well prepared and very informative.

T. E. Moffitt
President
Hooker Chemical Corp.



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by **Neil P. Ruzic,** *editor & publisher, Industrial Research*

The Technical Entrepreneur *plus fact*

NOW THAT THE National Council of Economic Advisors has turned the rate of U.S. economic growth into a presidential campaign program, the role of research & development is seen to be more important and less understandable. Statements are being made to the effect that research during the 1960s will net a push-button job for every worker, a chicken in every infrared oven, and an economic growth rate equal to the USSR's.

Of course research alone cannot yield prosperity or even a single dollar, much less an economy. Madmen, nuclear bombs, panic, depression, cosmic storms, sunspots, the black death, and all their equivalents historically have determined the regulation of man's wealth which we term "the economy."

Yet if we can ignore these variables for a moment we can distill the research factor *(R)* and isolate it as a chemist does an element. Then we can mix in the human catalyst and note the quickened reaction.

The research factor — defined here as the economic force of industrial science and innovation — is both old and new in our history. Along with immigration, natural resources, and hard work, it was a cause of three industrial revolutions that gradually eased the American economy upward. Now, largely because of our tomorrow-based credit economy, research (work done today for future profits) is the prime mover of the present, fourth, and greatest industrial revolution.

Four industrial revolutions

Three previous "revolutions," each lasting about 50 years, helped push the economy upward. The first industrial revolution was based on the mechanization of cotton ginning and on the utilization of steam power and iron. The second revolved around the railroads and steel. The third was sparked by electric lighting and the automobile, and the attendant rise of organized labor.

The first three industrial revolutions, extending from the end of the Revolutionary War to World War II, were begun by a tiny handful of entrepreneur-inventors — people like Whitney, Fulton, Morse, Edison, and Ford.

The fourth industrial revolution, ours, is unique in the number of people working on it, its complexity, and power to push the economy at a rate previously impossible.

Today, between 5,000 and 50,000 *technical entrepreneurs* (top R&D engineers, leading scientists, and highly-effective technical managers) are directly analogous to an estimated 50 to 500 men in all of the first three periods. Thus about 100 times the effort in terms of qualitative (effective, creative, patent-producing) manpower is being spent on the fourth revolution as on the other three combined.

Total manpower, of course, is much more than that: there are probably 700,000 engineers and industrially-oriented scientists in the U.S. today, as against 2,000 even as late as Edison's first high-voltage light bulb. Whereas Edison worked with 20 to 100 scientists in his laboratory, and Fulton labored alone, there are 5,000 industrial laboratories today employing from 20 to 7,300 technical men each (the latter at Bell Labs).

Today's technical men are making great strides in becoming more technically effective. In the beginning we had one kind of engineer, the civil engineer, whose business it was simply to change the face of the earth. Today we have mechanical, chemical, electrical, nuclear, aeronautical, and other engineers, doing specific parts of a more expanded task. Even now, the field again is changing as interdisciplinary talents are being brought to bear on complicated industrial and military systems.

The new engineer

Tomorrow, instead of the mechanical or electrical engineer, we will have the "systems or operations" engineer, the "topologist," "materials synthesist," "logician," and the "molecular engineer." These men will be educated equally well in mechanics, electronics, nuclear energy,

equals a helluva decade ahead

metallurgy, materials, and other areas of classical physics, chemistry, and mathematics. But more than that they will be taught to see the interrelationships of these sciences and how they can be combined in development of a system such as an aircraft or an automated bottling plant.

The evolution of the new engineer is being accompanied by an evolution in the non-"professional" technician. The dividing line, as reflected in engineering education, seems to be higher mathematics. Good technicians will be required in greater numbers despite their lack of mathematical sophistication. (Engineering colleges today are faced with the paradox of encouraging technicians but of not allowing technicians to graduate, even with a sub-professional degree, from the same institution. The job has been taken up by trade schools and junior colleges, where the title "technician" is an honor instead of a stigma.)

The "new engineer" and the "new technician" are emerging normally if not rapidly, but something is missing: there are no signs that their growth is being paralleled by "technical entrepreneurs." The creation of technical entrepreneurs is more than a problem of education. It is a problem of attitude, of almost inherent desire — of risk-taking in a society founded on risk but now prosperity-lulled and security-ridden.

In both government and industry today, there are too few people who are allowed or encouraged to make far-reaching, overall decisions. Concentrating nearly ultimate control in the hands of top management or government bureau heads inhibits initiative and slows the rate of innovation. The research group leader who anxiously waits while his project is being reviewed and then demonstrates bitter disappointment when it is killed usually can blame his own lack of entrepreneurship or technical salesmanship as much as "management."

Let's take a closer look at such professional technical men, both in "the ranks" and in management. The average engineer has a BS and about a year's work toward an MS degree in one of the engineering disciplines, and has been continuing his education on the job ever since, while getting paid for it. It has been eight years since his first degree and he now works at his third job, in a large engineering or research department.

He earns $8,500 a year, attends technical meetings, is intrigued by what's new technologically in his own and related fields, but pays little or no attention to overall economic company affairs — even when he's part of a company, like General Electric, which sells the concept and the reality of technical progress as its most important product. Like the average American, he can tell you more about the Chicago police scandals or the White Sox' record than he can about liabilities, assets, marketing potential — the scorecard — of his own company.

Technical management

His technical boss typically holds the title of research director. He earns $15,000 a year, has had less formal education than most of the 52 engineers who work for him (a BS bestowed 16 years ago), speaks at technical meetings, and is interested in new developments not only in his own and related fields but throughout all industry.

He pays attention to the economic affairs of his company because, as a part of management, he is forced to attend interdepartmental meetings. These he considers a nuisance, for he has pledged himself to his own department — to such matters as fighting for raises on behalf of his staff and to acquire better equipment.

He is part of top management, but does not regard his decisions as *the* most vital to his company. He refers to his nontechnical partners-in-management as "management." He voices his opinion freely on which projects to pursue or abandon, but does not resist effectively when "*management*" vetos him. On that nebulous, ill-defined scapegoat he blames all apparent mistakes and crises.

Nontechnical management

A typical nontechnical executive is the sales manager. On the same, averaged-out scale as we have portrayed the research engineer and the research director, the sales manager 16 years after graduation earns $20,000 when you include his incentive bonuses or commissions. He has a BS in marketing and considers himself part of the management team. He is interested in the economy of his company and of the nation, but lacks the technical background and creative insight to contribute much to either. He considers research as something to be "romanced" in sales — window dressing for the stockholders' report.

In considering these arguable, never-precisely-typical averages (drawn from five- to three-year-old salary and job surveys) we discover that neither technical management nor nontechnical management is capable of effective managing. Neither group can see or understand the overall picture. Neither type of man is truly capable of being president of the company in the science-soaring sixties.

Similarly the average nonmanagement engineer, despite his greater formal education, is doing little to train himself to become a better manager than his boss.

What is needed is the combination of the technical and nontechnical executive in a single person, the man who has the rare ability to be creative, to administrate, to promote, and to *want to take a risk* — the man we have been calling the "technical entrepreneur."

Entrepreneurs: creative or administrative?

Many studies of creativity and administrative ability have been made to define various entrepreneur types. O. S. Ohmann, of Standard Oil of Ohio, defines the administrator as orderly, systematic, one who moves according to plan. He likes to improve and perfect; he prefers to adapt to his environment instead of risking everything on a hunch. He has self-discipline; he is controlled.

The creative man, the innovator, on the other hand, is inquiring, unorthodox, often unpredictable, restless, willing to risk everything on his decisions. He abhors red tape, resents authority arbitrarily imposed by a nontechnical boss, and ignores authority arbitrarily imposed by a technical boss. He thinks in terms of goals, not methods. He may be organized, but he is not an organizational man.

Of course most people are combinations of the two. But a combination man who is proficient, happy, and highly effective is rare indeed. The combination is the technical entrepreneur, the Morse or Edison or Ford.

Such a person need not found an electric power industry or spearhead the automobile era. There is plenty of room for him throughout industry — as director of research, chief engineer, or project leader.

The rare, but typical, technical entrepreneur thinks in terms of his company's and industry's technical and economic position as well as of his own department. He thinks not only of the widget under development, but, for instance, of his own real salary. He knows that roughly 25% of his department's or company's payroll is being wasted in the utilization of human resources. He personalizes the waste. He thinks of management not as "they" but as "us," and once he has passed this hurdle he merges his firm's goals with his own. By creating work situations beyond the limit of his authority, he focuses his attention on his own job while at the same time accepting responsibility for the company as a whole.

An engineer or a scientist is capable of developing a product or process. A technical entrepreneur does not stop with development; he goes on to enforcement. Like a political party leader in an election, he invites thorough skepticism (of an invention or a line of investigation). Yet once the decision to follow a train of research is made, or to promote an innovation to management or the market place, he sticks to it with persistence and faith.

Assuming that technical entrepreneurs will be neither plentiful nor completely absent from our society, how can we assess their impact on the economy of this new decade?

30-million more consumers

The "soaring sixties," as General Telephone & Electronics and other firms have been advertising, will see some 30-million more consumers added to the American market. In turn, a 59% boom in consumer spending, from $313-billion to $500-billion a year, is predicted. This would yield an average family income from the present $6,000 to about $9,000 a year.

All this and more is possible in five to 10 years, but it is far from a sure thing, and it won't come about automatically. To happen in 1970, it requires *a steady annual growth rate of 5%* (almost 1½% more than the post-war average). In addition, it requires capital funds.

The supply of capital lately has gone up faster than the demand, and yet the price of borrowing, or the interest rate, has gone up! Capital now is plentiful; it is the conditions under which investors permit capital to flow that are intensely restricted.

Heavy taxation is behind the paradox. Our tax structure is such that capitalists are looking for new businesses that are profitable even after taxes consume half the profit. Failing that, they currently are intrigued more by certain tax-free bonds and by the opportunities in manipulating stock investments for tax-cheap capital gains than they are in new enterprises.

This kind of thinking is being done by the present captains of industry, who are financially oriented. Technically motivated entrepreneurs—there are some—point to new production, new markets, and new enterprises as the way to make a buck. And the path to these accomplishments is research.

Technical innovation on a large scale — our factor *R* — not only can be profitable, but broadens our economic base. In fact we can achieve a greater per capita prosperity and keep pace with the Soviet growth rate *only* through increased innovation. It is not entirely a matter of progress, but of running faster just to stay in the same relative place.

Since World War II, the U.S. gross national product shows up on a graph as a wiggly, though fortunately diagonal, line, dipping from a growth rate of from 2 to 4.3% — averaging 3.6% per year.

The Soviet growth rate

Depending on whose figures you use, the Soviet GNP has climbed from 6% to 9% each year during the fifties. The conclusion of most American economists is that the Soviet GNP has been growing roughly twice as rapidly as that of the U.S. during the past decade.

Even assuming that the United States GNP during the present decade can be increased to an average 4%, the Soviet GNP will be slightly more than 50% ours by 1965 and about 55% by 1970, according to Dr. Norton Dodge, professor of economics, University of Maryland. Soviet GNP is estimated now to be 45% of ours.

If the Soviets can continue to grow industrially by 8 or 9% per year (9% is planned), they could attain about 60% of our industrial production by 1970, provided our industrial growth rate averages 4½% per year. Any decrease in our rate of course would narrow the gap. For example, if the U. S. rate were to average the 2% which Khrushchev believes is the best we have in us, the Soviets' industrial production could be more than 80% ours 10 years from now.

The difference in a single percent of growth is enormous. An average 3% rate over each of the years of this decade would mean a gross U. S. national product of $680-billion by 1970, while a 5% rate would mean a GNP of $900-billion by that year.

A key to these trends is not merely a good average growth rate, but a stable one, for a growth rate of 4% is more likely to turn into a 5% rate in a non-fluctuating period than in an up-and-down, recession-boom economy. It follows that any large new factor that tends to stabilize our economy will help it grow, apart from its other merits.

Factor *R* does this, not only through the creation of new products, new industries, and new markets, but also by the forced, quicker, obsolescence of inferior products, uncompetitive industries, and worn-out markets.

Research creates technology, which permits an even greater expenditure for research. Thus the cycle gets larger and larger.

On the other hand, some economists argue that moderate recessions and even depressions *contribute* to growth. They reason that recessions force business to step up efficiency — either to cut costs, create new markets, or to seek new innovations. They point to long-term GNP charts, where the Great Depression shows a mere dip, and suggest that the depression didn't make much difference after all in the overall picture.

Without getting emotional about it, quite a few people who suffered through the depression would not so minimize its effects. Neither would the research director who saw his R&D budget slashed in 1958. The "recession-is-healthy" view

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might have appeared reasonable 20 or even 10 years ago when the only important factors in the economy were investment, labor, government, and markets. Today, when you add to those factors the stability and growth potential of widespread, systematic, $13-billion-a-year-and-up research, you come to this conclusion:

Any recession, any "panic" severe enough to curtail autonomous investment in research, will affect long-term growth adversely. Moreover, the adverse results will tend to multiply themselves, because not only growth but the very rate of growth is affected.

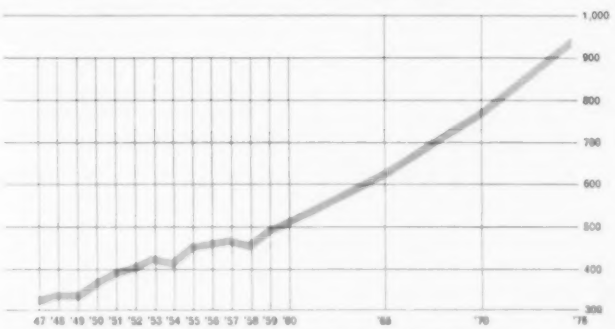
Is depression possible?

Observing the gloomy trend of the stock market since the beginning of this year, some nervous investors began to find parallels to 1929. One executive recently was quoted as saying, *"I read about a symposium of 25 big-business leaders in 1929. They all said the country was headed for 10 years of the greatest prosperity the world had ever seen.*

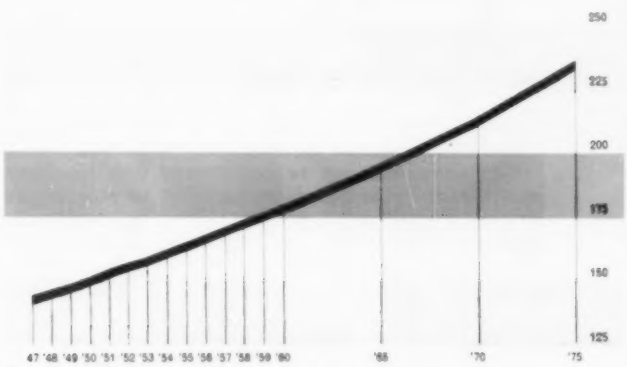
Certainly there is a similarity in the "soaring sixties" predictions and those preceding the thirties. But because research, bank stability, and other factors are so strong in the economy, a depression like the one in the thirties may be impossible.

Yet even a half-as-bad depression, at this stage of technology, could destroy the nation. One reason is that our population is expanding so fast (1.8% per year) that we must grow economically to keep the same standard of living per person. Another is that our competitors on the eastern side of the planet also are looking at growth and harnessing factor *R*.

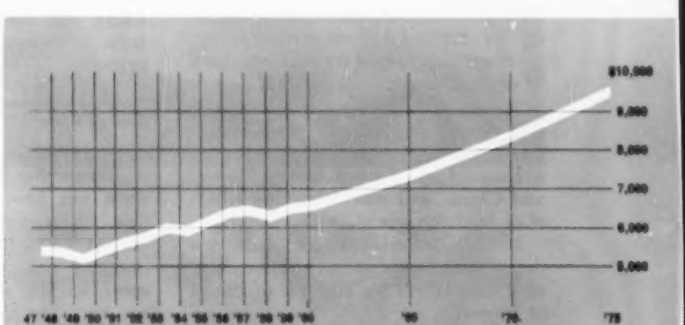
It is an ironic but distinct possibility that the system of government may not matter much in the end so far as techno-economic success is concerned. Totalitarian-communism, republican-democracy, and other



GROSS NATIONAL PRODUCT, *projected above in billions of dollars, is based on a 3½% rate-of-growth guess. Estimates are: $500-billion for this year; $610-billion for 1965; and $925-billion by 1975.*



U. S. POPULATION *is estimated to grow from 180.1-million in 1960 to 195.7-million in 1965; 213.8-million in 1970; and 235.2-million in 1975.*



INCOME PER FAMILY, *now averaging $6,500, should increase to $7,300 in 1965; $8,300 in 1970; and $9,400 by 1975. (American-Marietta Co. charts)*

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forms of government are not the sources of economic security they make themselves out to be. Economic security is based primarily on the production of wealth, and governments produce no wealth; they merely take it and distribute it.

The long-run

Nor will the present state of the nations' bankrolls make much difference in the long-run. Consider Germany since the war. From a demoralized, gutted nation, Germany has risen to a leading position in the European community. In the last analysis, money energy is merely efficiently directed human energy; capital investment is only a transferable form of human capital. Education, drive, versatility, knowledge, inventiveness, and proper direction of such human qualities — these are the vital resources of the United States, Russia, and China, and will determine which shall lead the world.

But can material progress sustain a nation's economic growth forever, you may ask. Won't we run out of things to invent?

A future fiction writer projects this problem to 35th century man, who by then has solved interstellar travel, electronic thought transfer, planetary engineering, immortality, etc., and comes up with the answer "no." Each new discovery, each new accomplishment adds immeasurably to the knowledge of what is unknown. Until we run out of planets, disease, advanced education, and prosperity for everyone, the question is hardly worth consideration.

The job to be done, technologically and technosocially, is enormous, as is the effort going into it. The startling thing to remember about the near future is the fantastic amount of human resources behind industrial research — comparatively for the first time. Some $160-billion will be spent during the sixties on R&D, and most of it will go in one way or another for technical salaries.

This decade can match our entire history

While dollar figures are difficult to comprehend, a comparison will show just how much is planned for this 10-year period: *it is an amount of human energy exceeding all of the energy expended on research, development, science, and pilot-plant technology since the formation of the nation.*

The laboratories of the sixties can put 2,000 men to work on a single missile or leave a few men alone to develop tomorrow's equivalent of a transistor. Yes, they will continue to be plagued by a shortage of competent men. And no, sheer numbers of engineers and amounts of money will not guarantee neo-transistors.

We will hear even more about the shortage of engineers of which we have heard so much. In one way or another, it will be resolved. As Dr. L. R. Hafstad, General Motors vice-president of research, suggests, the resolution of the shortage will follow this sequence, the first lasting about five more years and the others a decade each:

- A continuation of the hectic recruiting campaign with more and more fantastic starting salaries for anyone with a semblance of scientific training, followed by . . .
- A marked deemphasis on quality in the technical colleges to meet the increasing demand for quantity, followed by . . .
- A period of progressively diminishing returns to industry and society from the attempt to substitute quantity for quality in a creative activity, followed by . . .
- Disenchantment with paper credentials as a substitute for education. This will result in a return to appreciation of scholarship and achievement, but may be followed by a renewal of the cycle.

(continued on page 20)

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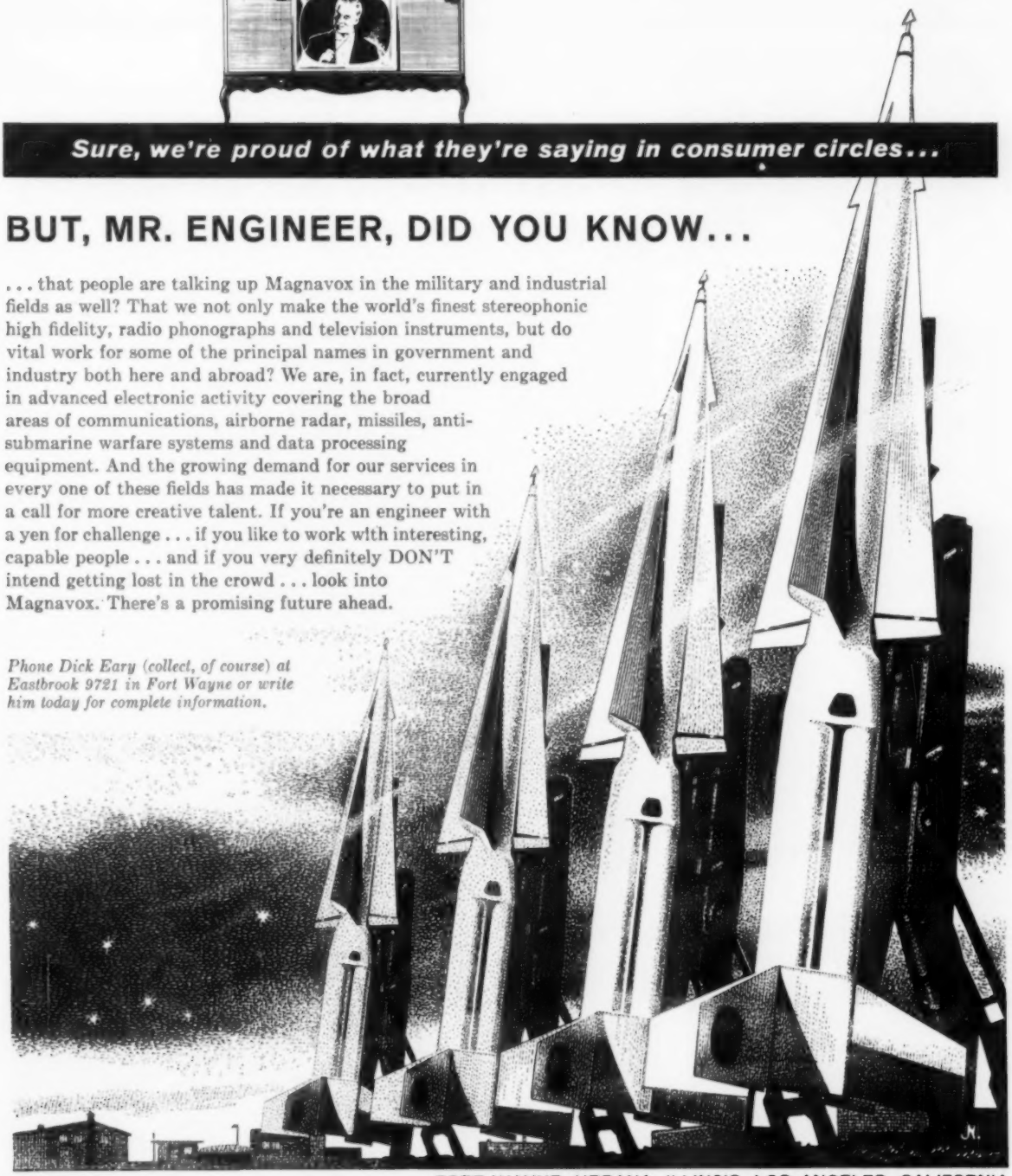

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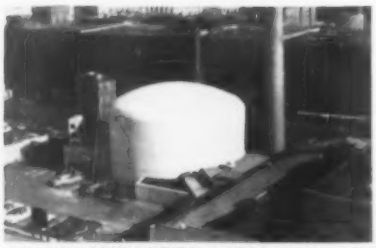
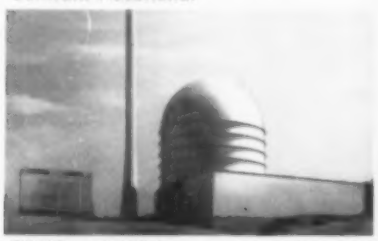
Some of the Allis-Chalmers nuclear projects around the world



MASSACHUSETTS: 1,000-kw research reactor for Massachusetts Institute of Technology.

HOLLAND: 20,000-kw research and materials-testing reactor for Reactor Centrum Nederland.



OHIO: 10,000-kw reactor helps Air Force simulate high-altitude, nuclear-powered flight conditions.

NEW JERSEY: Princeton University scientists, researching thermonuclear fusion, will use a full-scale Stellarator facility engineered and equipped by Allis-Chalmers and Radio Corporation of America.

Allis-Chalmers speeds world-wide progress in nuclear power

Helping provide power for a growing world has been part of the corporate way of life at Allis-Chalmers for more than a century. Power . . . from coal, oil, gas, falling water . . . and now, *atomic energy*. Pictured here is evidence that Allis-Chalmers is growing dynamically in this challenging field, offering unique capability to take nuclear projects all the way from "talk about" to "start up." Allis-Chalmers, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS

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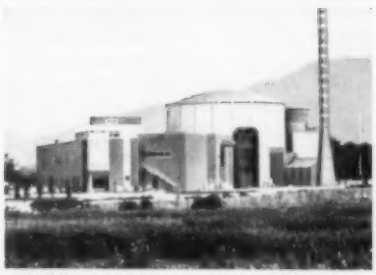
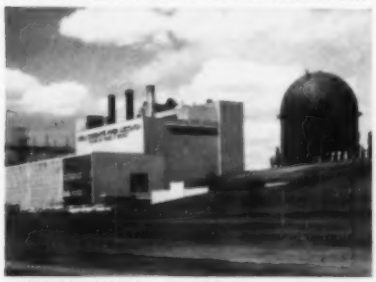


ITALY: 5,000-kw reactor for Italian National Committee for Nuclear Research.



MINNESOTA: 22,000-kwe power reactor for Rural Cooperative Power Association of Elk River.

SWEDEN: New 30,000-kw research and materials-testing reactor for Atomic Energy Company of Stockholm.

SOUTH DAKOTA: Architect's drawing of 66,000-kwe nuclear power plant with internal nuclear super-heat, now being designed for Northern States Power Company in cooperation with ten other midwest electric utilities.

TEAR OFF HERE

A QUESTIONNAIRE
for the technical man in industry

May we have five minutes of your time? Your answers to these questions will help I·R compile a profile of the typical R&D man, engineer, and technical executive in industry. Results will be compiled and presented in a later issue. Please tear out this page and mail to: The Editor, Industrial Research, 200 S. Michigan Ave., Chicago 4, Ill.

1. How would you characterize your work? ☐ research, or ☐ engineering *(check one or both if applicable)*
2. Do you consider yourself a technical entrepreneur (or the kind of person who will become one)? ☐ yes, ☐ no, ☐ possibly
3. Have you read the article about the technical entrepreneur preceding this questionnaire? ☐ yes, ☐ no
4. Do you agree with the point made in the article that this nation needs more technical entrepreneurs to effect a high rate of national economic growth? ☐ yes, ☐ no, ☐ undecided
5. How many patents do you have? _____granted, _____pending, _____being filed
6. How many technical papers have you published? _____
7. What percent of gross sales is spent for all R&D in your company? _____%, ☐ don't know
8. What is the highest degree you hold? _____ Have you done any work toward a higher degree? ☐ yes, ☐ no
9. What is your employment level? *(check closest category)* ☐ assistant engineer or scientist, ☐ associate, ☐ senior or chief, ☐ research or engineering department head or assistant head, ☐ vice-president, ☐ president
10. What is your annual base salary? $_____ Additional bonuses? $_____
11. Do you feel your formal education has prepared you adequately for your ☐ engineering, ☐ research, or ☐ administrative function? *(Check one or all if applicable.)*
12. Are you listed in American Men of Science, Who's Who in Engineering, or in a similar directory? ☐ yes ☐ no
13. Is your present place of employment your 1st, 2nd, 3rd, 4th, 5th, 6th, or more since graduation? *(Circle one.)* How long have you worked at your present company? _____ years.
14. About how much *more* money did you get on the average when changing jobs? $_____
15. How many times have you been promoted in your present company? _____
16. Do you believe ☐ engineering, or ☐ management offers the greatest opportunity for an engineer to advance? Which of these directions have you chosen for your own career? ☐ engineering, or ☐ management. If all other considerations were equal (salary, opportunity, etc.), which type of work would you choose? ☐ engineering, or ☐ management.

17. What is your total professional experience *(excluding college)?* _____ years
18. Do you now work: ☐ for a large company *(1,000 or more employes)*, ☐ medium-sized company *(between 1,000 and 100)*, or ☐ for a small company *(under 100)*
19. What is your political affiliation: ☐ republican, ☐ democrat, ☐ independent, ☐ other
20. Do you feel communications are adequate throughout your company? ☐ yes, ☐ no Within your department or section? ☐ yes, ☐ no
21. Do you think the missile race with the Soviet Union could be improved in favor of the U.S. by spending ☐ more for research, ☐ more for education, ☐ other _____ *(Check only one box that describes your main preference.)*
22. Do you exert an influence in specifying industrial products or services? ☐ yes, ☐ no
23. If your immediate superior is a technical supervisor, research director, vice-president of engineering or research, please answer the following:
    a. Do you feel your boss is technically *(scientifically)* qualified for his job? ☐ highly so, ☐ average, ☐ poorly qualified
    b. Is he sufficiently sensitive to your technical or professional problems? ☐ yes, ☐ no
    c. Is he sufficiently sensitive to your personal problems, including salary requests? ☐ yes, ☐ no
    d. Do you think he is effective in getting an equal share of appropriations, salary raises, equipment, etc. for his department or section? ☐ yes, ☐ no
    e. Do you feel your boss takes an important and as active a part in management decisions as he should? ☐ yes, ☐ no
24. If you are a project leader, technical supervisor, chief or senior engineer or scientist, or vice-president of research or engineering, please answer the following: *(Also answer question 23, if appropriate.)*
    a. Do you feel the men in your research laboratory are unduly sensitive? ☐ yes, ☐ no
    b. Do you consider morale a key factor in research creativity? ☐ yes, ☐ no
    c. Do you take as active a part in the overall management of your company as does the nontechnical executive? ☐ yes ☐ no
    d. Are you as effective in getting equipment, appropriations, and salary raises for your department or section as are the nontechnical department heads in your company? ☐ yes, ☐ no
25. Are you ☐ married, ☐ single, ☐ have children, _____ *(number)* Do you have boys between the ages of 8 and 18? _____ *(number)* Girls? _____ If so, are you trying to interest them in science? ☐ yes, ☐ no Any luck?
26. Was your father, brother, uncle, or someone else in your family a scientist, engineer, or technical executive? ☐ yes, ☐ no
27. Do you read employment ads in this magazine? ☐ regularly, ☐ sporadically, ☐ never
28. About how much time did you or will you spend reading *this issue* of Industrial Research? _____ hours.

PLEASE TEAR OUT AND MAIL. RESULTS OF THIS SURVEY WILL BE PUBLISHED IN A FUTURE ISSUE.

Entrepreneur . . .

Return to appreciation

By Hafstad's timetable, it will be 1985 before the "return to appreciation" will begin. Why should it take so long, and what can we do in the meantime to assure that the soaring sixties indeed will soar in a technological-economic sense?

Society's response time is so lengthy because engineers and scientists, who have been aware of this situation for so long, are after all a numerically small fraction of our population. Added to this is the fact that the effects of engineers' activities are delayed by the research-to-production time lag. Average U.S. lead time presently is eight years, as compared to five years for the USSR. Thus a complete work stoppage on the part of creative scientists and engineers in this country would not be felt by our society generally for almost a decade.

Lead time from research to manufacture may increase as the rate of research and technology itself increases simply because it will have to. Gen. Trudeau, chief of Army R&D, wrote in the Dec. 1959 *Industrial Research* that "planned telescoping" already has reduced lead time in some 14 missile projects to five years, eight months. Overall lead time has shortened from 10 to eight years in the past decade, and there is every sign that it will decrease further as foreign military competition and our own scientific productivity increase.

Cutting lead time

Industry and government can do more to cut lead time. As Trudeau suggests, industry can perform more research and production design at the same time—the systems engineering concept—and can disseminate information on new inventions and scientific breakthroughs more quickly. Government can cut lead time by improving decision-making in the evaluation of new weaponry.

But despite gains being made by industry and government men to shorten lead time, the fact remains that these same leaders are acutely unconscious of the vital need to encourage and train more technical entrepreneurs. They remain apathetic to Hafstad's 40-year "technical appreciation" cycle.

Why? Because most government and industrial leaders are nontechnical controllers or entrepreneurs. You might assume that enlightened self-interest would demand that they do more with the basic problems involved in their struggle for defense or wealth. Since they do not, you have to assume that

such interest is not enlightened—not, at least, technically so.

Granted that we need technically enlightened business men—or business-enlightened technical men—where do you find them?

The answer is that you do not find such men, you create them. You do not train men as they now are being trained, nor do you rely on your company's nontechnical personnel department, conventional recruitment advertising, good will, high salaries, green-grass-surrounding-the-lab, educational opportunities, and all the rest. You create the man by making him the kind of offer that would eliminate lesser men. Or if you are the engineer, you seek the kind of offer that others would not consider.

The economist Clarence Danhof pointed the way to such an offer. He distinguished between "fabian entrepreneurship," characterized by the stereotyped banker who bets only on a sure thing (and sufficient collateral), "imitative entrepreneurship," characterized by the business leader smart enough to recognize a good idea and go into competition with the original exploiter, and "innovating entrepreneurship," characterized by the kind of man we're talking about—the technical man capable of organizing and commercializing innovations.

Hindsight tells us that Robert Fulton was such a person. Fulton did not invent the steamboat (some 30 of them had been built prior to his *Clermont*); he was the inventor of the practical steamboat industry. Morse founded a telegraph company; he did not invent the telegraph. Edison's bringing of the electric light into general use should be attributed to his capital-raising ability, his technical salesmanship, as much as to his inventive genius.

And there are current examples: Simon Ramo and Dean Wooldridge, William Shockley, John Eckert, Jacob Rabinow, Jonas Salk, Edwin Land, and others.

Incentive for the soaring 60s

These men have one thing in common. Incentive. Some can find incentives within large corporations; others begin their own companies, and of the ones who do, most are driven to it.

Scientific incentive is often sufficient, but more often it is not. Financial incentive as a principle of management, should begin at the lowest level of technical-management possible because the lowest echelon of creativity is the largest and therefore the most vital in our pyramid-shaped corporations.

In your own firm, what is the annual salary for an engineer, project leader, or research director who merely does the job? What is it for the man who develops or leads the development of 10 patentable innovations during the year? Or for the man who devises a labor-saving process, or guides his company into a more fruitful technical area?

Surveys indicate that if you are in the average industrial company you will earn a mere 1 to 15% more per year if you are an innovator, a potential technical entrepreneur, than if you are not. *(In the interest of learning more about the technical man, Industrial Research has included a questionnaire on page 19 and 20. Please fill it out; results will be tabulated and published in a later issue.)*

Ultimate recognition

Cartoons have lampooned the Soviet practice of pinning medals on the chests of worthy producers. We, in our capitalism, have a much more potent weapon of reward, the universally accepted, pratical mark of total recognition: the dollar.

Wherever responsibility and control are divided, efficiency suffers. Leaving innovation to a sense of altruism, hobbyism, or poorly motivated curiosity is not good enough if we are to achieve the ultimate. **If project leaders or technical supervisors are not responsible for the decisions they make—if they are not penalized for mistakes and rewarded for success—they will not be as efficient as those entrepreneurs subject to the pressures of a competitive market.**

You may object that it is difficult to pay creative men in proportion to their effectiveness, and of course it is. Salesmen can have commissions, but a project leader or research director must work for a salary that is within a narrow range the same salary he can make at a dozen other corporations.

Certainly our giant corporations capable of successfully tackling multiplex telephony, earth-circling satellites, equitable invoicing for users of electric power, nuclear propulsion, and thousands of other complex problems can devise incentive salaries for the technical entrepreneurs who are their greatest asset.

To admit inability to provide incentive compensation is to admit inability to gage the effectiveness of a creative man. If such an admission is made, it is made by a management that does not consist of technical entrepreneurs. ■

(Reprints of this article are available. One copy is free; two to 25—50¢ ea.; 26 to 50—40¢ ea.; 51 or more—35¢ ea.)

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Wide range of applications: the RPC-4000 has been designed for engineering, scientific, business data processing and management control functions. Such jobs as product and process design, statistical analysis, research, inventory control, payroll and sales analysis are all well within its capabilities.

Easy to use: the RPC-4000 is simple to program and operate. Royal McBee compiling and translating routines allow even non-technical personnel to obtain maximum results. Versatile command structure gives programming speed and flexibility.

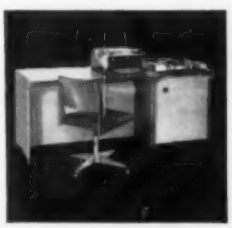
Available at low cost: high capacity, flexibility and ease of operation make the RPC-4000 the outstanding computer value on the market today.

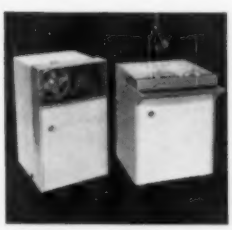
Minimum operating costs: the RPC-4000 requires no site preparation or special maintenance. It is powered from any ordinary wall outlet.

Continuing assistance: users benefit from free training, an information exchange service, and library of programs.

Heart of the RPC-4000 system is a new transistorized computer with advanced design concepts that provide substantial computing speed and capacity in a low-cost unit. Magnetic memory drum stores *8008 words*. Operating speeds are as high as 230,000/minute.

Standard input-output is a tape typewriter system which includes a Royal electric encoding-decoding typewriter complete with desk and chair, plus a tape punch-read console. Read speed is 60 characters/sec., punch speed 30 characters/sec. Typewriter, punch and reader may be interconnected in any combination for both on-line and off-line operations.





A new 500 character/sec. photoelectric tape reader and a 300 character/sec. punch are available as optional input-output equipment. A magnetic tape unit and a line printer will be available soon. As many as 17 input-output devices (60 with minor modification) may be connected on-line to the basic system. All peripheral equipment is under automatic program control of the computer.

Royal Precision Corporation

Royal Precision is jointly owned by the Royal McBee and General Precision Equipment Corporations. RPC-4000 sales and service are available coast-to-coast, in Canada and abroad through Royal McBee Data Processing Offices. For full, detailed specifications on the new, transistorized RPC-4000, write **ROYAL McBEE** data processing division, Port Chester, N.Y.

thermocatalytic combustion:

heat without flame

OURS IS A THERMODYNAMIC world. A more basic characterization of the universe is impossible because the concepts of heat and energy are synonymous. While it is relatively easy to produce heat, progress is dependent upon its efficient conversion.

Heat engines produce heat, but wastefully dissipate much of it in the conversion to mechanical power. Devices generically called "heaters" also produce heat, but their task is to impart this energy to other bodies or fluids. The key to the useful application of heat, therefore, is its conversion or transfer. This is as true of a jet engine as it is of space-heating equipment.

Startling heating devices

The following discussion presents a development called "thermocatalytic combustion," which is destined to revolutionize heating. Within the year startling new products built around this development will begin to appear on the market:

- A central home heating system, slightly larger than a portable TV set, requiring no chimney, absolutely safe, 95% efficient, and competitively priced.
- A radiant heater capable of more than 150,000 Btu/hr per square foot, operating at temperatures of more than 2200 F for comfort heating outdoors or in hard-to-heat hangars, warehouses, etc.

In the near future, other thermocatalytic devices will take the form of:

- Engine pre-heaters, de-icing equipment, steam-powered tools, drying kilns, immersion heaters, pipeline heaters, paint dryers, wire and strip annealing furnaces, chemical processing equipment, heat-treating furnaces for metals and ceramics, high-temperature hand torches, petroleum cracking reactors, heaters for bituminous products, smoke and odor eliminators, air conditioners, evaporators, dehydrators, boilers . . . the list is endless.

The revolutionary character of thermocatalytic combustion can be appreciated better after a look at conventional combustion processes. Basically, all conventional combustion systems are identical, and they have undergone virtually no change since the demise of coal-fired appliances.

The inefficient flame

Gaseous or liquid fuels are burned in most heaters today, such as boilers, space heaters, water heaters, furnaces, or torches. In these, heat is produced by the oxidation of hydrocarbon compounds, and manifests itself as an incandescent gas volume known as a flame.

Were this process permitted to take place without the addition of air, a luminous yellow flame would result due to the incandescence of carbon present. The addition of air yields the familiar blue flame of domestic and commercial gas-burners.

Any interference with this phase of oxidation results in incomplete combustion. For example, when a cold metal surface is brought into contact with a flame, the disruption of the combustion process gives rise to partially combusted products such as carbon monoxide, aldehydes, and carbon.

Now that chemical energy has been changed into thermal energy, means must be provided for its transfer. In virtually all heating appliances in use today, this is achieved by allowing the flame or the flue gases, or both, to impinge on a surface. In water-boilers, for instance, primary transfer is accomplished through convection to a heat exchanger. The heat exchanger then surrenders its acquired energy

by **Gerhart Weiss,** *director of research and engineering, American Thermocatalytic Corp.*

American Thermocatalytic Corp.'s new "thermocatalytic combustion" may change our reliance on bulky, inefficient furnaces and present heat-treating methods.

by conduction to a distribution system containing water as the transfer fluid.

Two premises:

- If the quantity of heat liberated in the combustion process equals the energy content of the fuel, the production of heat is optimum.
- If the temperature of the flue gases leaving the boiler equals that of the water in the boiler, maximum attainable transfer efficiency has been achieved.

Unfortunately, neither case is ever realized in practice. Open-flame burners always require an excess of air in order to achieve an acceptable (but never complete) degree of combustion.

Production is easier than recovery

In spite of this limitation, however, it is far easier to produce heat efficiently than to recover it efficiently. Conventional combustion devices resort to extensive heat abstracting surfaces which attempt to recover thermal energy from the flue gases by direct contact.

This transfer mechanism — which depends upon the collision of hot gas molecules with the metallic surface of heat exchanger and baffle — is an inefficient, random process. The operation of a natural convection system further requires wide flue passages, large masses of metal, and a chimney.

It is axiomatic that the temperature of the exhaust cannot be less than the temperature required of the appliance. Thus, neglecting dilution and scavenging, if the required temperature of a transfer fluid is 200 F, the flue gases must be 200 F or higher.

The proximity of these figures determines transfer efficiency. Nearly all present-day heating equipment exhausts at much higher temperatures, inspiring cooler air in order to meet maximum stack-temperature codes. Minimum operating efficiencies of new equipment are controlled fairly rigidly by various standards. The actual operating efficiency of a heating plant is evaluated better after some service than at the time of installation.

However, general design practices (especially in oil-fired equipment) cannot avoid the gradual deposition of soot on the heat-exchanger surfaces. It is precisely this insulating layer of soot which destroys efficiency.

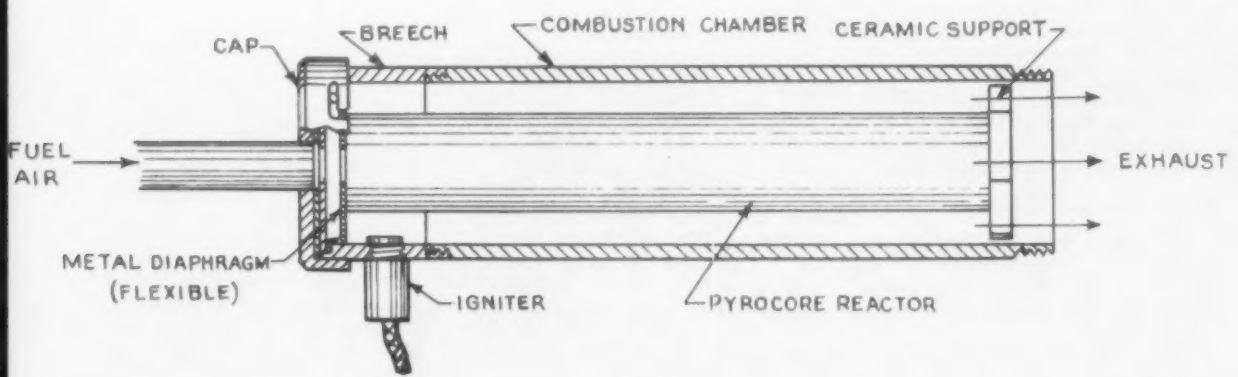
Improvements, limited

Because of the inherent nature of all conventional combustion systems, radical improvements such as miniaturization, freedom of position, near-perfect efficiency, elimination of tall stacks, complete suppression of explosion hazard, increased economy of operation, rigid control, and economical employment of high-grade materials *simply are not possible.*

Power-burners and forced-draft systems have reduced some of the shortcomings of conventional systems. Alone, the power-burner makes possible higher input rates in a given space and, by supplying the requisite amount of primary air for combustion, efficiency is improved considerably. Yet, the standard exhaust stack and its attendant inconveniences remain. Here, forced-draft helps appreciably.

It stands to reason that if the exhaust stream is moved mechanically by a blower rather than by natural draft, the stack can be made smaller (limited by the pressure available from the exhaust blower), and a greater amount of heat can be recovered by the use of additional heat exchangers.

At first look, therefore, it would appear that the combination of a power-burner and a forced-draft device presents the solution to all combustion equipment problems. Disre-



MODULES OF THERMOCATALYTIC HEATING, *at left, produce 10,000 Btu/hr. Two such modules can boost heat from room temperature to 1400 F in five seconds and to 1650 F in one minute. Diagram above shows thermocatalytic, "Pyrocore" reactor installed in a combustion chamber.*

The beginning of Gerhart Weiss' research in thermocatalytic combustion dates back to an early paper of his on a thermoelectric diode converter which he wrote during the war for the Signal Corps. A graduate physicist, Weiss holds several dozen patents in controls, plastics, electro-mechanisms, polarizers, pneumatic devices, and heating systems. He is director of research and engineering at American Thermocatalytic Corp.

garding the size and high cost of such devices for the moment, this would be true if the character of the flame itself were different.

The basic failing of the open flame lies in the fact that the heat which it gives off is almost completely convective and not radiant . . . and thereby hangs a tale:

Vanish the flame

In a high-temperature industrial furnace, a flame is thrust against the refractory walls instead of merely being allowed to burn within its confines. Those who have seen the bright incandescence inside such a furnace may have noticed the absence of flame. To be sure, the flame was present when the furnace was lighted, but it has been replaced by a high-temperature catalytic reaction.

The reaction occurs when the furnace walls attain a sufficiently high temperature. Energy is transferred to the work-piece predominantly by radiation from the hot furnace walls. This form of energy transfer does not follow the rules of convection and conduction. It is not based upon contact, and does not require extensive transfer surfaces. Actually, in outer space it is the *only* form of energy transfer.

Let us examine the differences between radiant and convection heating. We know that the convection heating action of a flame is highly directional, specifically upward. You can hold your hand quite close to the side of a very hot flame without much discomfort. This is so because the flame does not radiate appreciably.

Enter: radiant transfer

Now, place a bar of metal or ceramic into the flame and transfer conditions change. The object so heated would begin to incandesce and emit energy unidirectionally. (This form of *radiant* energy is known as target-impingement.) It would be intolerable to hold one's hand at the same distance from the incandescent body as from the flame alone.

Radiant transfer is powerfully effective when used properly. Power densities far in excess of those realizable with open-flame burners are the rule, and it is possible to transfer much more energy, at much higher efficiency, and in a smaller volume than can be accomplished by convection transfer.

It is clear, then, that the production of heat in the form of a flame is of limited value because it is extremely difficult to achieve efficient heat recovery from a volume of hot gas. In consequence, attainable levels of energy-transfer from the flame to the medium to be heated are low.

Evidently, a great need exists for an entirely new approach to combustion — one which makes use of the latest advances in physical and chemical research and benefits from the most recent developments in materials technology. The perfection of thermocatalytic combustion has foreshadowed a fundamental change in the modern concepts of combustion in all its aspects.

Thermocatalytic heat

A thermocatalytic reaction is based on the maintenance of a predetermined, stable combustion state involving the feedback of thermal energy from the reaction zone to a catalytically active layer beneath it. The layer is catalytic because the materials in it accelerate the reaction without themselves undergoing change. A catalyst, by definition, is an agent which accelerates or retards a reaction without partaking in it.

Thermocatalytic combustion, however, is not an example of true catalysis, but a combination of catalysis and heat. The excitation potential of the catalytic agents generally is high enough to permit maintenance of a localized high-temperature stratum in the reactor. In turn, this thermal stratum serves instead of a flame as a radiant emitter.

The nucleus of the system is a thermocatalytic reactor, called "Pyrocore." A typical Pyrocore reactor of 30,000 Btu/hr output, operating on any gaseous or liquid fuel, is a cylinder about a foot long and an inch in diameter. In operation it looks somewhat like a yellow fluorescent tube.

Actually, its surface is incandescent at about 2000 F, producing heat at power densities exceeding 1,000 Btu/hr per square inch. It is ignited electrically, cannot be blown out, and works in any position. Its most generally applicable shape is that of a porous tube, open at one end and sealed at the other.

A mixture of air and gaseous fuel is introduced into the open end under slight pressure and forced through the pores. Since the reaction takes place on the outer surface of the reactor, the combined effects of both radiant and convection outputs are available.

In convection service, the reactor generally is enclosed in a metallic chamber, followed by a relatively small secondary heat exchanger. The primary heat transfer from the reactor to the metallic chamber is achieved principally through radiation, and augmented by convection.

An effective re-radiator

In cases where the metallic chamber is an integral part of a heat sink, or where its heat can be imparted to a flow of air or liquid, the chamber can be kept reasonably cool. However, if left to operate in still air, the temperature of the chamber rises and becomes an effective re-radiator.

Up to 75% of the total heat output of the Pyrocore reactor may be transferred directly via this radiant chamber. In this mode of operation, the secondary heat exchanger has only about 25% of the total heat output to recover.

Because the system is force-fed, quite narrow passages are used in the heat exchanger, making possible miniaturization and high efficiency *(in some cases more than 95%)*. Also less volume is required, thus reducing the cost of material, shipping, and warehousing.

Thermocatalytic reactors may be

(continued on page 28)

Flames swept across the open plains as the Mongol hordes ran in terror from the "arrows of flying fire". When the smoke had cleared the Chinese had won the battle of Pienking with the first rocket.

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used directly in open air in non-vented applications such as furnaces and ovens, or radiant space heaters mounted in suitable fixtures. For vented applications, they are enclosed in ceramic or metallic sheaths from which the exhaust gases may be piped outside.

Since radiant power densities vary approximately as the fourth power of the emitter temperature, the attainment of sufficiently high temperatures is of great value in many industrial applications. These include process heating and drying; pre-heating of metal parts; drying of printing inks, paints, and paper stock; chemical syntheses; and personnel comfort heating.

Heat where you need it

Thermocatalytic heating systems can be designed to produce heat where it's needed (much like electrical resistance heaters in this respect), and no transfer medium need be employed to distribute thermal energy. This quality is of great advantage where the heat losses encountered discourage using transfer media.

For instance, when heat is generated at a central furnace and imparted to a fluid piped to a radiator, the fluid cools as it passes through the pipe. Thermocatalytic systems, however, generate heat at the location of the radiator, which is fed with the fuel-air supply. Hence no heat is lost in transit because no heat is transported through pipes and ducts.

Thermocatalytic combustion is characterized by an exceptionally clean exhaust — the result of virtually perfect combustion. The carbon monoxide content averages less than 0.01% in the undiluted flue gases, and even when operated with number 2 fuel oil, no soot is produced.

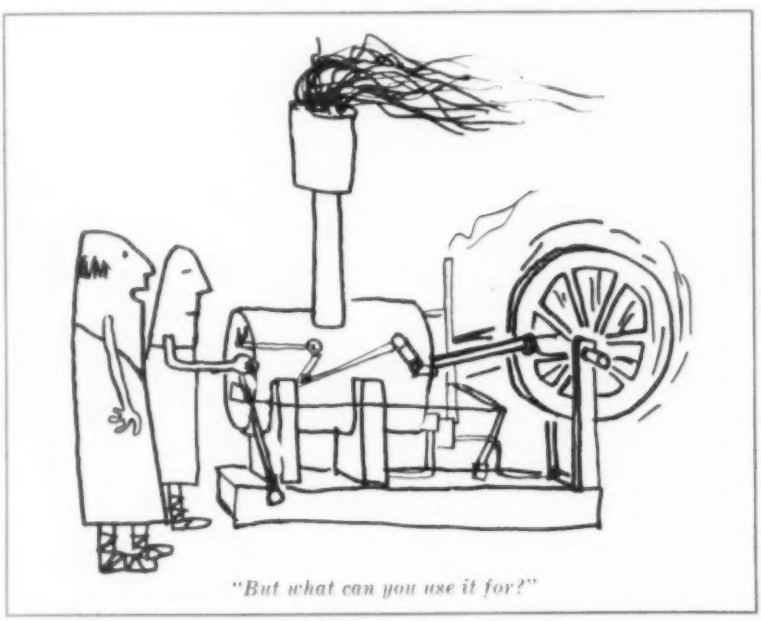
The Pyrocore unit can deliver more than 400 watts per square inch in free air, as compared with electric heaters which deliver up to 90 watts per square inch. Many jobs, however, require lower power densities than those afforded by Pyrocore — such as absorption-type refrigeration, environmental heating of electronic equipment and controls, and standby heating of engines.

A portable reactor

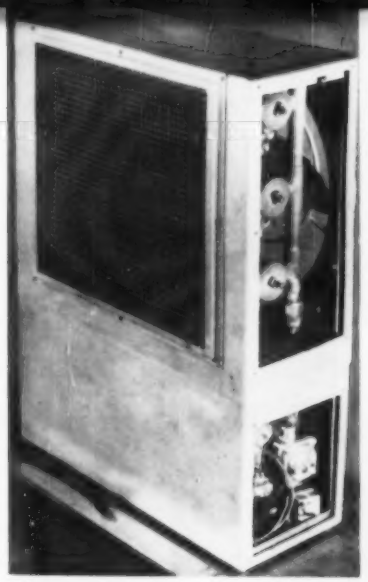
For these applications, a light, portable, 50-watt-per-square-inch, fully catalytic reactor called "Infracore" has been developed. It has the advantage that no power source is needed when operated with bottled propane gas.

In applications requiring uniform heat distribution over extended lengths, a flexible thermocatalytic duct has been developed. It produces a uniform heat output along its entire length—a feat which previously could be accomplished only by an electrically heated cable. Such ducts can be used as immersion heaters, personal clothing heaters, or pipe and gage heaters. The heating of pre-determined sections of the duct can be increased or decreased to conform to special requirements.

Thermocatalytic combustion devices also have shown themselves to be well adapted to thermoelectric generators. Several firms now are developing apparatus for the direct conversion of



"But what can you use it for?"



***MINIATURIZED** thermocatalytic heater is a gas-fired unit which measures 28 x 20 x 8 inches, and operates at 95.6% overall efficiency.*

thermal to electrical energy.

American Thermocatalytic Corp. expects Pyrocore one day to emerge as the nucleus of an inexpensive and highly efficient afterburner for the purification of automobile engine exhausts. Preliminary laboratory tests have shown a reduction of hydrocarbon content of the exhaust stream from 8,500 to less than 20 parts per million.

Build it yourself

In order to pursue as many avenues of application as possible, American Thermocatalytic has designed modules of radiant heating Pyrocore "blocks" to enable engineers in various industries to evaluate thermocatalytic combustion and to construct their own processing equipment.

The modules are of 10,000 Btu/hr. Two have been used to build a small furnace that heats from room temperature to 1400 F in five seconds or to 1650 F in one minute. Maximum working temperature at present is 2200 F, but 2500 F is feasible.

Ordinarily several hours or even days are required to bring furnaces to such temperatures. In conventional heating units the fuel cost is extreme, particularly in high-input installations which must be kept hot throughout the night or over weekends. Use of thermocatalytic radiant modules can save up to 50% in equipment cost over conventional units.

It may take some time before these units reach full exploitation, simply because their applications are so vast. But the era of thermocatalytic combustion is upon us, and it will replace flame furnaces as surely as furnaces have replaced fireplaces. ■

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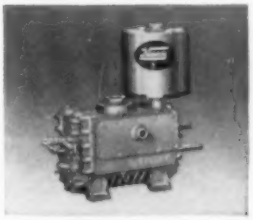

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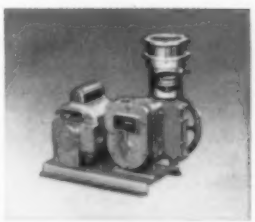

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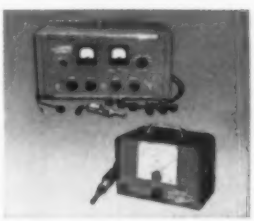

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ULTRA- and HYPER-SONICS

ONCE USED mainly to call dogs and to provoke scientists' curiosity, the science of inaudible sound called ultrasonics and hypersonics is taking over more and more jobs in industry, military systems, and research.

Ultrasonics (originally called supersonics, a name now used to describe speed faster than sound) can be said to have started in 1883 with the Galton whistle. Capable of producing sound waves of a frequency higher than could be heard by human beings, such whistles were used to demonstrate the reflection, interference, and propagation properties of sound.

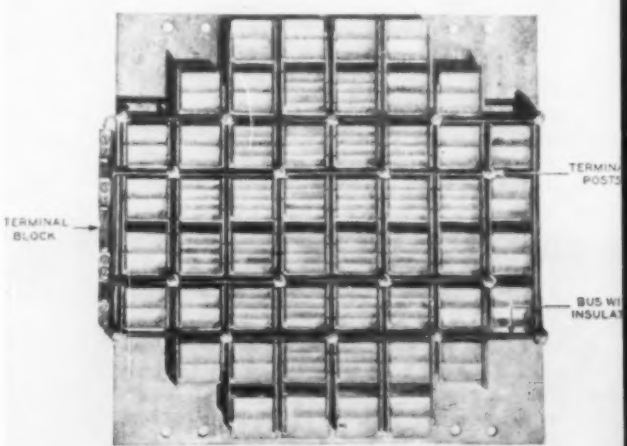
Submarine detection

During World War I, some submarine detection work was done with ultrasonic waves transmitted through seawater. Between world wars, ultrasonic fathometers were developed to measure the depth of the ocean accurately and quickly. The technique has universally replaced the old lead-weight method, standard up to that time.

In WW II the extensive applications of ultrasonics for both detecting and destroying submarines (by ultrasonic homing torpedoes) contributed materially to allied victory.

At about the same time ultrasonics made its appearance in industry with the invention of the ultrasonic "Reflectoscope" by Firestone. Using a high-frequency sound pulse, reflections were obtained from relatively small imperfections and cracks in metal castings, glasses, and ceramics. Such methods also have been used to inspect the quality of adhesive bonds in automobile tires and other products.

ULTRASONIC CLEANER, *above, by Westinghouse, is a 300-gal. unit for complete immersion of large parts. Below, a 25-kc transducer described in text sends a sound pulse into the ocean; when it strikes a submarine it produces an electrical response.*



At Bell Telephone Laboratories, where he has been associated since 1921, Dr. Warren P. Mason leads research on wave filters, piezoelectric crystals, solderless connectors, and ultrasonics. Mason has authored three books: Electromechanical Transducers and Wave Filters; Piezoelectric Crystals and their Applications to Ultrasonics; and Physical Acoustics and the Properties of Solids. He earned his BS from the University of Kansas, PhD from Columbia University (in 1925), and is a Fellow of the Institute of Radio Engineers, and the American Acoustical, American Physical, and the Audio Engineering societies.

by **Dr. Warren P. Mason,** *head, mechanics research, Bell Telephone Laboratories Inc.*

Today, high-amplitude ultrasonic waves disperse fog and clean air of dust particles. Ultrasonic cavitation boils away contaminants from parts being cleaned, breaks polymer chains, sterilizes milk, and produces new alloys and more uniform, smaller grain sizes in castings. Ultrasonic drilling, welding, and soldering are developing rapidly.

In the lower-power range, besides sonar uses, the propagation of sound waves are used in pulse-decoding systems, information storage for computers, and inspecting materials and parts for flaws. Current military applications include moving-target indicator sonar systems and mechanical filters for radio and communication systems.

How it works

Ultrasonics simply is mechanical vibration occurring at frequencies higher than can be heard by the human ear — about 16,000 cycles per second. Any mechanical vibration requires some medium for transmission: it can be a gas, liquid, solid, or combination of these. The vibration is a means of transmitting energy from one point to another by subjecting the particles or elements of the medium to oscillatory forces and movement. Various oscillating modes are possible depending upon how the particles of the medium move with respect to the direction of propagation of energy.

Waves called longitudinal vibration have alternate compression and expansion of the medium in the direction of energy propagation, as in a clarinet. Another type, transverse waves (also called shear waves) is exemplified by particle motion transverse to the direction of energy propagation, as in a taut string with one end moved up and down. Wave motion in a body of water is somewhat more complex, with particles near the surface moving in elliptical paths.

Necessary components of ultrasonic systems are the transducers, which convert electrical energy to mechanical energy and vice versa. One type of transducer, for instance, uses a piezoelectric crystal, an element with the property that certain physical dimensions change when an electric field is impressed across opposite faces, and conversely. Another type uses magnetostrictive (and ferromagnetic) material, which changes its physical dimension when a magnetic field is impressed along the material.

High-power applications . . . for gases

One of the simplest uses for high-power ultrasonic waves is in the precipitation of fog, dust, and chemical mists from air. Ultrasonic methods for cleaning gases are applicable when no electrical charges occur on the particles and electrical precipitation cannot be employed.

The action depends upon the fact that lightweight particles can follow air vibrations whereas heavy ones cannot. Hence, light particles are brought into contact with heavy ones and stick to them, reducing the number of small particles. The heavy particles eventually fall to a collecting plate or can be pulled there by means of an electric field.

The process has been applied in industrial smoke precipitation. It was found that a siren-type generator is usually most efficient in producing the necessary high-intensity ultrasonic waves.

. . . for liquids

For liquids, most of the mechanical effects of ultrasonics are due to cavitation; that is, high-intensity sound waves produce countless microscopic cavities, or actual holes, in the liquid. These cavities first grow in size and then violently collapse many thousand times a second. When the bubbles burst inwardly, they set up a scrubbing or "cold boil" action that virtually blasts the contaminant from the substance being cleaned.

Ultrasonic cleaning of metal parts, watches, and jewels is used widely in industry, and a number of firms, such as General Electric, Clevite-Brush, Gulton Industries, Massa Laboratories, Narda, and Branson Ultrasonics produce commercial units. Watch cleaning by ultrasonics is particularly common. Anything from complex gear trains to microscopic bearings — or virtually anything made of hard or semi-hard plastics, metal, glass, or ceramics — can be cleaned ultrasonically with conventional equipment.

It is claimed to be from two to 10 times faster and from 30% to 100% more effective than other cleaning methods. Companies already using ultrasonics have found it cuts costs impressively because it not only does a faster and better job, but means less tie-up of needed parts and actually can fit into production-line operation.

Now the outlook is for continued expansion of ultrasonic cleaners and for entirely new devices. The effects of cavitation can be used to disperse metals, sulphur, and silver grains in photographic plates; extra fine-grain

ULTRASONICS TODAY

can be used to:

- Improve the grain structure of steel ingots.
- Make spot welds and seam welds on aluminum foil.
- Operate devices to clear fog and smoke
- Detect flaws in castings.
- Measure wall thickness of pipe and plates from one side.
- Clean small metal parts and jewels.
- Locate fish or submarines.
- Store information in delay lines for military antijamming equipment.
- Study motions in gaseous, liquid, and solid sound-transmission mediums.
- Measure acoustic attenuation in metals and semiconductors.

ULTRASONICS TOMORROW

will be used to:

- Produce new alloys.
- Improve the cooling of steel.
- Fabricate atomic fuel elements.
- Clean radioactive parts.
- Make solder adhere to any hard surface if dipped in a bath of molten solder.
- Weld plastics to plastics, even plastics to metal.
- Extract volatile constituents from spices, and flavor from coffee.
- Emulsify foods so they will not separate.
- Sterilize milk.
- Vaporize fuel oil and give better carburation.
- Separate one voice channel from a multi-channel signal.

photographic emulsions have been produced in this way. Sterilization of milk results from the destructive effects of cavitation on bacteria. Chemical effects, such as the uniform breaking of polymer chains and the speeding of chemical reactions, are also the result of high forces produced by cavitation.

One of the most potentially useful effects of cavitation is in its control of metallurgical processes. Westinghouse researchers have investigated the solidification of a melt as enough ultrasonic energy is applied to cause cavitation in the molten stage. They find that the grain size is much smaller and more uniform when subjected to ultrasonic vibration.

Since fatigue strengths increase for small and uniform grain sizes, such treatment well may improve the properties of castings. The dispersive effects of cavitation also have been used to produce a new series of alloys, such as lead-aluminum combinations, which cannot be made by other techniques since these metals ordinarily do not mix.

. . . for solids

High-power waves in solids are generated mainly by producing a large motion at the end of a metallic horn. This motion has been used in such ultrasonic devices as drills, welders, soldering irons, and equipment to test fatigue and measure internal friction under high-power vibration.

All of these devices employ a transducer to convert electrical energy into mechanical vibration. Transducers contain a piezoelectric crystal or a magnetostrictive driver that generates the mechanical vibration, and sometimes a horn-type structure, working at resonance, for amplifying the motion at the end of a tapered metal horn. The driver is located at the wide end of the horn, and the part to be vibrated is at the narrow end. It can be used to study the fatigue properties of metals.

A shaped tool attached to the end of such a transducer system and an abrasive turns it into an ultrasonic drill that can cut any desired shape in a brittle material. If the abrasive is diamond chip, hard materials such as tungsten carbide, sapphire, and even diamond itself can be drilled or shaped. Ferrite magnetic material is more easily shaped this way than by other methods. A variety of ultrasonic dental drills also have been developed.

By mounting a tool at right angles to the axis of the horn and exerting a static pressure on the moving part of the tool, it has been found possible to weld two thin pieces of metal together. The action appears to be due to a combination of shearing stress, normal stress, and increased temperature.

A variation of the welder is the ultrasonic soldering iron which can be used to join metals to aluminum. The drawing at right shows a soldering iron of this type made by the Mullard Co., of England. The ultrasonic vibration generated by a magnetostrictive driver removes the oxide coating from the aluminum and allows the solder to wet the clean aluminum surface. Soldering then can take place without the use of a flux.

Low-power applications

. . . sonar

Since the power output of transducers used in sonar equipment necessarily must be below the cavitation point of seawater, sonar can be classified as low-power ultrasonics. From the point of view of total monetary expenditure, sonar is undoubtedly the largest application of ultrasonics.

Much of the current work is highly classified, but the principles can be illustrated by WW II devices. The photograph on page 30 shows the face plate of a 25-kilocycle transducer used to send a directed beam of sound waves into the ocean. Each transducer material is an ammonium dihydrogen phosphate (ADP) crystal vibrating at its quarter-wave frequency. The outer set is twice as thick as the inner set and, since they all are connected in parallel to a common voltage source, the inner set moves at twice the amplitude of the outer set to produce greater directivity.

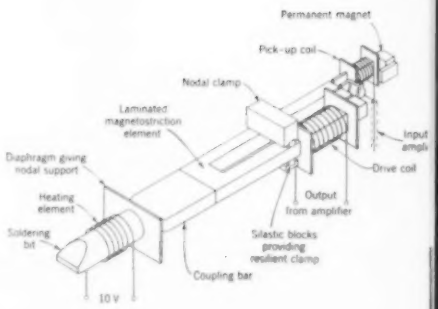
A pulse is sent out and reflected back from a submarine or other obstacle, producing an electrical response on a recorder connected to the transducer. By timing the return pulse and determining its direction by rotating the transducer, a submarine or school of fish can be located. The transducer can pick up directly the noise generated by the submarine as it moves through the water.

A variation of this technique also has been used to guide torpedoes toward submarines or surface ships. The entire operation is similar to the process used by a bat to guide itself.

. . . flow detection equipment

Another variation, applied to solids, has produced ultrasonic flow-detection equipment for examining castings and other metal parts. Parts as long as 20 feet are commonly inspected.

Frequencies in the 500-kilocycle to 15-megacycle range are used. The size of the flaw that can be detected is determined by the wave length of the transmitted sound, which is inversely proportional to the frequency.



By using wide-frequency-band transducers, very sharp pulses can be obtained and flaws close to the transducer can be detected. Ultrasonic instruments also can be used to measure the thickness of parts—such as boiler walls or oil pipe—for which only one surface is readily available.

. . . ultrasonic delay lines

Information in the form of very short mechanical energy pulses can be stored in a solid material and reproduced when these sound waves reach an output transducer. Such a transmission path with input and output transducers, is known as an ultrasonic delay line. The drawing below shows the form and size for a "wedge type" ultrasonic delay line having a delay of 500 microseconds.

Other military uses of delay lines are as timing devices for producing a signal a specified time after an initial pulse is sent out. The Germans probably were the first to use solids, in the form of glasses, to produce short delays as components of artificial targets and of antijamming devices.

Recently a variable-type delay has been investigated. It makes use of the fact that group velocity in a wire or strip of material depends on the ratio of the sound-wave length to the radius, or thickness dimension, of the wire or strip. Delay variations as large as 50% of the total delay can be realized by

changing the frequency of the pulse. Several important applications may be expected for such devices.

Delay lines with magnetostrictive wires as the transmitting medium are used in a pulse-decoding device for a system of navigational aids known as "navar." In England, delay lines of the liquid mercury-type and also magnetostrictive wires are applied as information storage devices for computers.

Total dollar investment for delay-line products is probably second only to sonar in ultrasonic applications.

Also of interest is transmission of ultrasonic waves through mechanical filters for separating one discrete voice channel from a group of voice channel frequencies. Filters using mechanical elements, are proving themselves in broadcasting receivers and in carrier- and radio-transmission systems.

An ultra-tool for research

Ultrasonic waves are useful as research tools to determine motions that can occur in gaseous, liquid, and solid sound-transmission mediums.

One of the simplest devices, the torsional crystal, has shown that moderately viscous liquids have elastic properties as well as viscous properties. This elasticity contributes to the load-carrying capacity of lubricated bearings and gears operating at high speeds. Studies are being pursued on the elastic and viscous properties of oils which may produce lubricants having superior qualities over present products.

Measurements of acoustic attenuation in metals and semiconductors, carried out at high frequencies and low temperatures, have established the interaction of acoustic waves with such physical entities as electrons, dislocations, and vacancies. Experiments in a magnetic field have revealed the form of the Fermi surface (which determines the flow of electrons) for single crystals.

By measuring the attenuation for superconducting metals, information has been obtained for the superconducting process which confirms theories of superconductivity. Internal friction measurements at high-strain amplitudes conducted by the writer have shown a correlation with the mechanisms causing fatigue in metals. By going to very small grain sizes and by inducing initial strain, fatigue stress in certain alloys can be increased.

Hypersonics

The most recent and in some ways the most exciting development of ultrasonics is called "hypersonics" — the production and utilization of frequencies above 1,000 megacycles.

These frequencies are high enough

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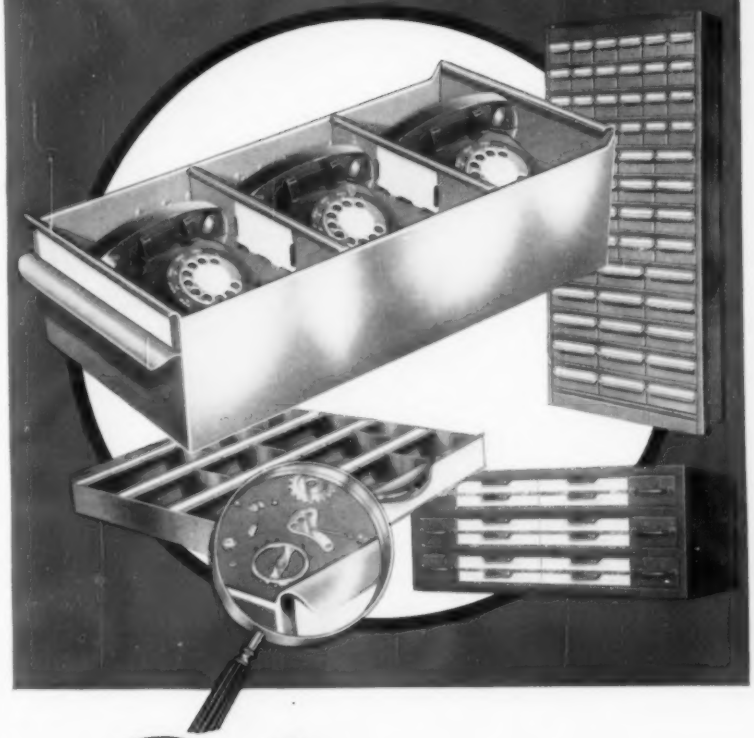

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and the wave lengths short enough for the acoustic waves to interact directly with such fundamental quantities as the "phonon." (A phonon is a quantum of sound energy, or a quantized sound wave, which constitutes the thermal energy of a nonelectrically conducting body.) The acoustical waves also interact with electrons and holes which carry the electrical and, to a great extent, the thermal energy of conducting and semiconducting solids.

Furthermore, at these high frequencies, processes such as the motion of magnetic domain walls (or boundaries between small, magnetically homogeneous sections in ferromagnetic materials and the motion of dislocations in metals and crystals provide less attenuation for sound waves in solids.

The importance of this frequency range was long recognized. Efforts to reach it were pursued by the usual techniques of attaching very thin quartz crystals to solids by means of thin layers of greases or cements. Leaders in the field were Dr. J. Lamb at the Imperial College of Science & Technology of London, H. J. McSkimin of Bell Laboratories, and R. Truel of Brown University, who have reported measurements up to 700 megacycles.

The difficulty with further extending the range by their technique is in the small sizes of the crystals required and the deleterious effects of using even the smallest possible seals. Some new principles of sound generation were needed.

Crystals as microwave components

A breakthrough came recently in which the microwave cavity was wedded to the piezoelectric crystal. This idea dates back to the end of WW II and in fact was tried experimentally by John Slater at MIT and W. G. Cady, then working at California Institute of Technology. In the light of later successes it appears that their failure to observe any effect was due to the high frequencies they employed.

For such frequencies, the attenuation of sound waves at room temperatures is so high that no excitation can be observed more than a few thousandths of an inch from the source. The first success with this technique was obtained by the Russian physicist, K. N. Baranskii working in the frequency range from 100 to 1,000 mc.

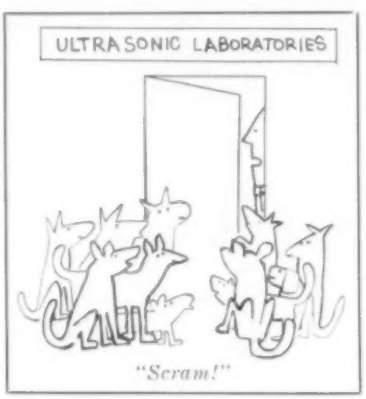
By employing a quartz rod mounted in a waveguide cavity, Baranskii succeeded in generating longitudinal waves in quartz rods. He observed their presence by using as an optical diffraction grating the dense and rarified parts of the quartz produced by the acoustic wave. At the lower-frequency range the attenuation was low enough so that the presence of the wave could be verified.

Dr. H. Bömmel and Dr. K. Dransfeld of Bell Laboratories extended these results by transmitting waves from one cavity and picking them up and detecting them in a second cavity. When the output was compared with that from a calibrated electrical connection between the input and output, it was possible to make good attenuation and velocity measurements.

Shear waves in solids

Bömmel and Dransfeld demonstrated that the acoustic waves are generated at the surface of the crystal and they follow the usual laws of sound transmission in a crystalline medium.

One of the first important results obtained by their technique was that



the attenuation of a sound wave nearly disappears at a temperature of 30°K and lower, and a condition very near to superacoustic conductivity results. Bömmel and Dransfeld first achieved this result by measuring the attenuation of both longitudinal and shear waves as a function of the temperature down to liquid helium temperatures.

The absence of attenuation proved that acoustic waves lose coupling to the thermal waves — the phonons — which carry the thermal energy. This was to be expected from theoretical considerations, but the experiments provided the first verification of the theories.

Spin waves

Recent tests show that shear hypersonic acoustic waves can interact with the spin waves present in a ferromagnetic substance. Magnetic properties of a ferromagnetic substance are related to the spin of atomic electrons on their own axes or their movement in orbits around the atomic nucleus.

For ferromagnetic materials the distinct magnetic properties have been shown to result from the spin of the electrons on their axes. In a given ferromagnetic domain, all spins are in the same direction so that all the elementary magnets contribute to the total magnetization of the domain.

These spinning electrons act like gyroscopes and can be given a precession (circular movement) around the spin axis when a constant magnetic field is applied in the approximate direction of magnetization.

Spin waves were invented to account for the fall-off of the magnetic moment (or strength of the elemental atomic magnet) as the temperature increased. According to a theory of Nobel Prize winner Felix Bloch, spin waves are excited by thermal energy, and, since they cause the spin axis to deviate from the magnetic domain direction, they cause a loss of the effective magnetic moment as the temperature increases.

Bömmel and Dransfeld have shown that such waves have an actual existence and can be affected by hypersonic shear waves.

Other groups also have employed the hypersonic sound-wave technique. Dr. E. H. Jacobsen and collaborators at General Electric Co. have used such techniques to study paramagnetic resonance and the superconducting process at hypersonic frequencies. They have produced frequencies as high as 10 kilomegacycles by this process.

Toward phonon frequencies

Work both at General Electric and Bell Laboratories is directed toward raising the attainable frequency from 35 to 1,000 kilomegacycles. If the frequencies can be raised to 1,000 kilomegacycles, waves corresponding to direct phonon frequencies at room temperature can be studied. At present the only information available in this range comes from studies of neutron diffraction in materials.

Investigations of the properties of liquids at hypersonic frequencies are being conducted at Catholic University under the direction of T. Litovitz. He has found the new technique of producing waves by cavity excitation convenient since the same rod can be employed over a wide frequency range by tuning the microwave cavity. Other groups, in California and elsewhere, have taken up the hypersonic techniques and many useful results may be expected.

So far the interest in hypersonics has been as a tool for physical investigations, but applications resulting from pioneer work usually take directions that can not be foretold. ■

BEFORE

Mockup of large stainless steel valve.

AFTER

Specially designed and tailored Glas-Col heating mantle in place on valve.

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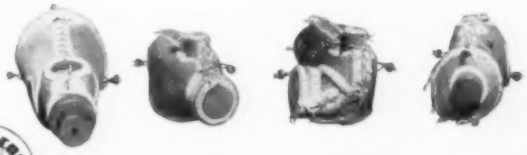

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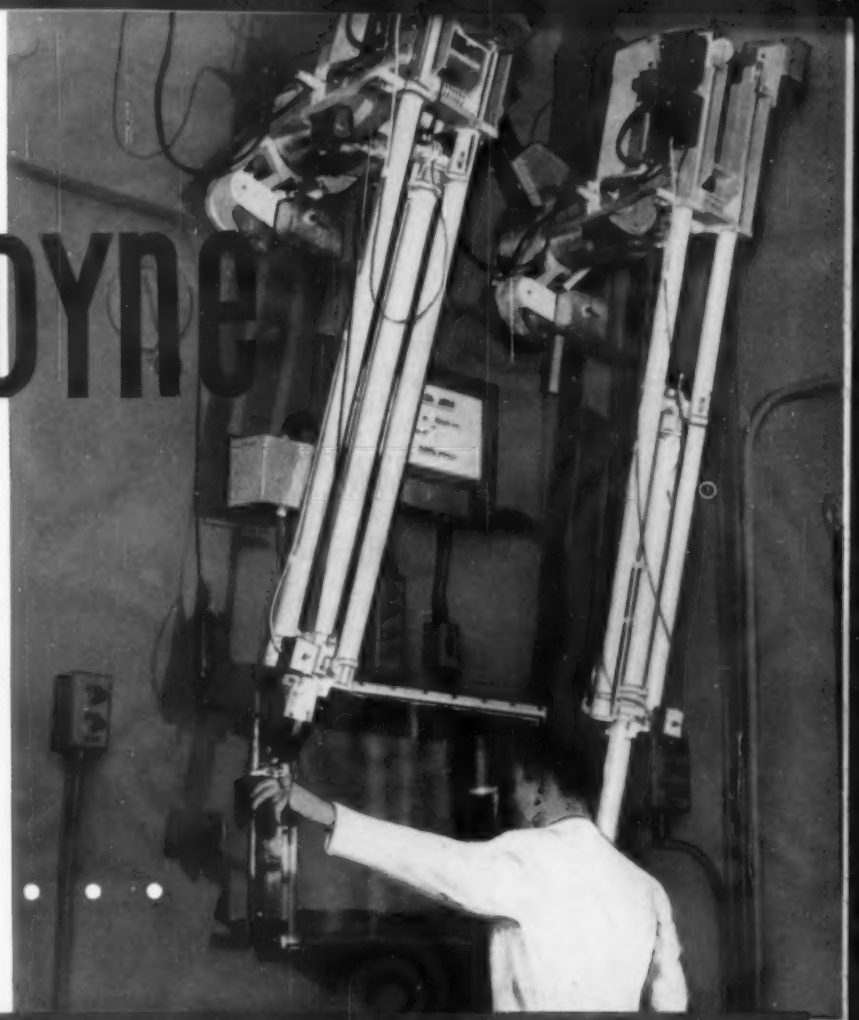
Looks Into The Future . . . .



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TYING THE FARMS of Missouri and the cattle ranches of Oklahoma to their Chicago market place, U.S. highway 66 paves a broad, four-lane path through southern Du Page county, Illinois. It is the last lap for truckers on their way to the city, 25 miles to the northeast.

A few passers-by may have noticed the flashing yellow lights marking the access road leading to one of America's foremost nuclear research establishments. This is Argonne, where 3,700 scientists, engineers, and supporting workers are exploring the peaceful potential of atomic energy (1).

Half of what goes on at Argonne is research for its own sake, with the thought inherent that the more we know about nature, the better off the world will be. The other half is development to the point where industry can utilize laboratory-found knowledge. A typical research problem is finding out how an atomic nucleus decays. Determining the best way to protect a reactor fuel element from corrosion is a typical development problem.

There are 16 scientific and engineering divisions at Argonne, the Atomic Energy Commission's most diversified and second largest national laboratory (Oak Ridge is first).

There are 100 buildings with more than 2-million feet of floor area on the 3,700-acre site. The physical plant represents an investment of about $100-million; laboratory equipment, much of it found nowhere else in the world, is worth about a third of this sum. One of the more spectacularly equipped new buildings is the fuel fabrication facility (shown in 2 and on the cover), the first complete plant for processing plutonium in an inert (helium) atmosphere.

2

3

There are reactors. Lots of them: nine in operation or under construction at the Illinois site, six in Idaho. Argonne's Experimental Breeder Reactor-I in Idaho produced the first electricity from atomic energy; its Experimental Boiling Water Reactor (EBWR) in Illinois was the United States' first full-scale atomic power plant; its BORAX-III (BOiling water ReActor eXperiment, now dismantled) first produced enough power to light a town, in Idaho.

(If you think Americans are good at stretching initials to spell out words, consider the French: they've named a rapid reactor being built in southern France the RAPSODY.)

Even the laboratory's steam-heating lines (3) resemble sections of scientific apparatus. Above ground for easy maintenance, they loop every few hundred yards to allow for thermal expansion and contraction. The EBWR (background), now undergoing modification, soon may furnish steam for these lines.

Equipment for basic research attracts scientists from all over the earth. A 12.5-BEV synchrotron now under construction will have the most intense particle beam of accelerators of its type. A cyclotron, a linear accelerator, three Van de Graaffs (one of them under construction), and two Cockcroft-Walton accelerators head the list of specialized equipment, which would fill several volumes if complete.

But just as the instruments of an orchestra are only as good as the musicians who manipulate them, Argonne's impressive scientific instruments are only as good as the research investigators who utilize them. The man who conducts the research program is the key.

Laboratory director Dr. Norman Hilberry (4) got his start in physics when cosmic rays were still the most familiar sources of sub-atomic particles. He studied cosmic radiations on top of Colorado's Mt. Evans and at the

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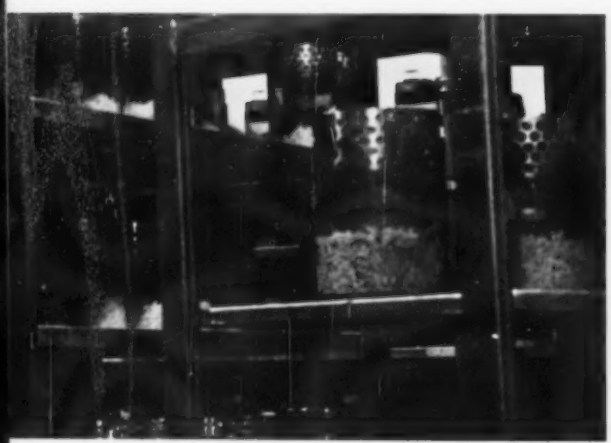
summit of the 19,200-foot volcano, El Miste, in southern Peru. With the outbreak of World War II, he helped guide Chicago's Metallurgical Laboratory (Argonne's predecessor) to attain the world's first chain reaction.

Argonne grew out of the thinking and planning of people like Dr. Hilberry and Dr. Louis A. Turner (5), now deputy director. Wartime experience had shown that scientists in many fields could work together on their own researches and still contribute collectively toward solving a problem of vital national importance. The war had catapulted America into the atomic age. So many new questions were being asked that the Argonne kind of organization became necessary to deal with them.

The visitor to Argonne immediately is struck by an immense variety of activity. In touring the biology building, he enters a square room 24 feet across where mice and



other small animals are exposed to varying amounts of gamma radiation (6) and (7). Aim of the experiment in progress, involving thousands of mice, is to discover new facts about cancer.

Stepping outside, he visits one of many new construction sites (8). Here they are building a low-flux, special purpose, research and training reactor.

In the physics building his attention is first captured by three big electronic computers. One, named GEORGE ("Let George do it"), was designed and built at Argonne. Another, an IBM-704, recently acquired a 32,000-word magnetic core memory. The third, a PAGE analog computer (9), is a valuable tool for simulating reactor control problems.

In another building he watches a technician carefully seal a sodium-iodide crystal in an airtight container, part of a scintillation detector for a physics experiment (10). Argonne set up its own "dry room" for machining and packaging these crystals, which are extremely hygroscopic. In fact, the technician must wear a special plastic helmet to carry off the moisture of his breath.

In the chemistry building our visitor sees the spectroscopy section where scientists classify heavy-element spectra, determine nuclear spins and moments, and study isotopic shifts. To be analyzed, a heavy element sample is vaporized and placed in an arc (11). The light, directed onto a diffraction grating, produces several orders of spectra, which are recorded on photographic plates in a 30-foot circle. The scientist who works in the spectrograph

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REACTOR AREA
MONITORING METERS REQUIRED
BEYOND THIS POINT
CONTROL
HARD
HATS
NO ADMIT

16

room (12) sees only light from the instrument; his sole contact with the outside world is an intercom system wired to an FM radio receiver.

The heart of an atomic laboratory is its research reactor, and Argonne's heart is a reactor named CP-5. (13) The letters "CP" stand for "Chicago Pile," referring to the family of reactors which began with the historic Chicago Pile-1 under the west stands of Stagg Field on the University of Chicago campus. Thus, CP-5 is the great-great-grandson of the world's first reactor. Like most present-day research reactors, CP-5 is not a "pile" of graphite; it is a tank filled with heavy water containing uranium-bearing fuel elements, and its sole purpose is to furnish abundant radiation, primarily neutrons, for research.

More than 60 openings penetrate the sides and top of CP-5, providing access to neutrons within the reactor. Clustered around its eight sides are usually a variety of research equipment, such as a chamber for irradiating small biological specimens, a tank for measuring shielding properties of various materials, a bent-crystal gamma-ray spectrometer, a neutron chopper and time-of-flight apparatus, a diffusion cloud chamber, and an apparatus for studying the spin of neutrons.

Industrial Research visited CP-5 during a period of changeover, when scientists reluctantly had given way to construction workers. The reactor was being converted for eventual operation at 10,000 kilowatts, five times its previously-rated power. Similarly, EBWR is undergoing conversion which is expected to push its rated power from 20,000 to 100,000 kilowatts of heat. (14)

Both reactors will have new, larger cores of nuclear fuel. Higher neutron fluxes available at CP-5 will make it possible to conduct more experiments in shorter time. Similarly, a souped-up EBWR will allow better studies of reactor instrumentation and control. And faster fuel burnup in the power reactor will make possible more studies of fuel design and processing — all aimed at cutting the costs of electricity from atomic energy.

The laboratory recently completed a huge mass spectrometer (15) with 100 times the sensitivity and 10 times the resolution of smaller instruments. It is by far the largest of mass spectrometers; its mascot, built by the operating technician, is a dinosaur (16), the largest of animals.) The apparatus will be used to weigh atomic nuclei and thereby determine relative quantities of atoms or isotopes of different weights.

The formation of cesium-137 by fission of a nuclear fuel is a measurement of the amount of fuel that has been burned. In his calculations, the nuclear engineer must know exactly how fast this radioisotope is decaying; the giant mass spectrometer can tell him.

Atomic science is a science of new materials, and new materials demand new solvents and new separation processes — first worked out painstakingly in a crowded lab like the one in (17). Walk down a corridor in Argonne's chemistry building, and you find scientists investigating the solvent behavior of fluorides. Another group is studying molten metals as a means of carrying away impurities in reactor fuel. Another studies liquid-liquid fractionation of mixtures of heavy elements. Another has succeeded in preparing a hexavalent platinum compound (PtF_6) and is examining its properties. There is an interrelationship, a cross-over of research; it is the reason why laboratories like Argonne were started, and why they will continue to flourish. ■

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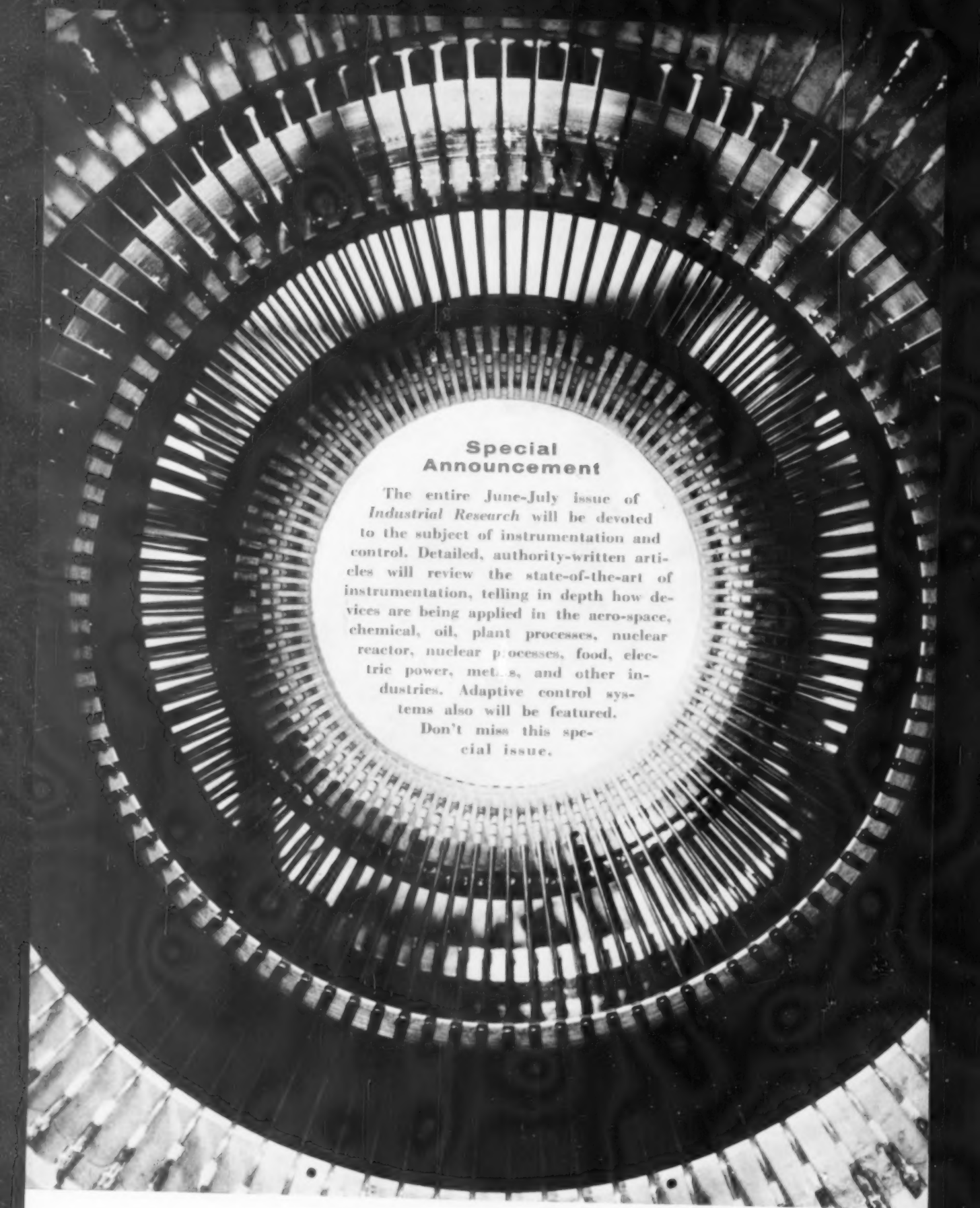
I•R photographs by Jon Pownall



Special Announcement

The entire June-July issue of *Industrial Research* will be devoted to the subject of instrumentation and control. Detailed, authority-written articles will review the state-of-the-art of instrumentation, telling in depth how devices are being applied in the aero-space, chemical, oil, plant processes, nuclear reactor, nuclear processes, food, electric power, metals, and other industries. Adaptive control systems also will be featured. Don't miss this special issue.

energy and civilization

SUNPOWER

Despite whether our fossil fuel reserves dwindle, as has been predicted, solar energy is becoming a practical power source in its own right. Several devices already have been built.

A NEW LOOK AT NUCLEAR RADIATION ENERGY

Most physicists agree that radioactivity, as a source of energy, has been vastly overrated. Radiation energy has its place, but it will have to go a long way to replace chemical processes.

OUR NUCLEAR SEAPLANE

Of the more obvious uses of nuclear energy is aircraft propulsion. Yet attempts to build the "A-plane" have bogged down in a sea of politics, an example of which is offered by this "one-act play."

OCEANS OF BUSINESS OPPORTUNITIES

There is more immediate potential under the sea than over the atmosphere, and the "laboratory" is easier to reach. Oceanography may be a more profitable pursuit than astronautics.

SUNPOWER

by **Jan Oostermeyer,** *president, Association for Applied Solar Research*

RECENT U.S. ATTEMPTS to orbit the moon with a "paddlewheel" satellite brought into sharp relief man's continuing efforts to harness the limitless energy of the sun. These tiny spheres are so designed that, upon going into orbit, four vanes emerge from their bellies. The "paddles" are covered with thousands of solar cells to convert the impinging sunlight into solar energy to power the satellite's radio and electronic equipment.

This striking example of the application of sunpower more than 200,000 miles away may seem unrelated to industry, but such progress leads daily to more "down-to-earth" uses. Solar energy study has progressed from the back yard of the amateur inventor to the research laboratory. It already has proven to have sufficient practicality so that business and industry have become active partners in its development.

An abundance of magazine articles recently have prophesied that sunpower will solve the problem of the impending exhaustion of our fossil fuel reserves. Yet advertisements in these same magazines which

Recently returned from a tour of Soviet solar energy research laboratories as a special guest of the USSR Academy of Sciences, Jan Oostermeyer is one of the world's leading authorities on sunpower. He has been president of the Association for Applied Solar Energy Research since 1953, when he retired as president of Shell Chemical Corp. Born in Holland, he joined Shell in 1917 at the Hague and served with the company in the U.S., China, and Chile. He was appointed an Officer of the Orange in recognition of service to the Dutch during World War II. His "retirement" includes extensive consulting for Food Machinery Corp. and other firms.

employ solar-energy principles seem limited to "gadgets" like solar cigaret lighters and portable barbecue cookers. The layman is amazed that solar devices exist at all; the businessman asks to see more practical applications; the technical man whether they can be adapted to his field.

Although most breakthroughs so far have been realized only in the laboratory, we can expect them to appear on the market before long in the form of salable products. Space propulsion and the large-scale production of electrical and mechanical power convertors will be realities in the near future. Major advances already have been made in the fields of communications; home heating, cooking, and cooling; sea water conversion; and solar furnaces for intense temperature research.

Solar space and time

Development of the silicon solar battery by Bell Telephone Laboratories in 1954 brought solar energy to the communications industry, where it now plays a small but increasingly important role. Both Hoffman Electronics Corp. and International Rectifier Co. produce thousands of tiny photocells a month for a variety of commercial applications. The cells used to power radio transmitters in the "paddlewheels" are of this type, as were those used in earlier U.S. and Soviet models. They also are used in portable radios, harbor beacons, highway blinkers, and toys.

Systems for applying sunpower to space-ship propulsion as well as communication are being investigated by several companies, including Westinghouse Research Laboratories, Lockheed Missles Systems Division, RCA Laboratories, Northrup Aircraft, and Thompson Ramo Wooldridge. Scientists at Westinghouse have proposed solar sailing as a means of propelling a ship in space. After escaping the earth's atmosphere, the ship would unfurl a large aluminum-coated plastic sail which could be of any size—even an acre has been proposed. The pressure of sunlight on the sail would move the vehicle much the same as the wind moves a sailboat.

At Thompson Ramo Wooldridge space scientists have developed beyond the working-model stage a self-contained sunpowered electrical system for space vehicles. Basically, it consists of a solar collector focusing heat on a mercury vapor boiler which drives a small turbo-alternator.

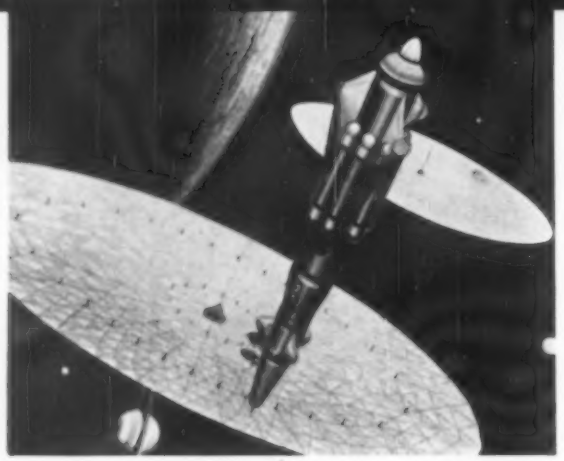
Solar-activated photoelectric devices now on the market include a solar clock manufactured by General Time's Seth Thomas Division, Zenith's solar-powered hearing aid, and still and movie cameras produced by Bell & Howell.

Recent price reductions announced by Hoffman Electronics (high-efficiency cells now cost $200 per watt and low-efficiency cells $100 per watt) undoubtedly will stimulate more commercial uses. But because their output is limited—about 100 watts per square yard of collection surface—solar cells will be used in the immediate future mostly in remote areas and for devices requiring only small amounts of power.

Simulating nuclear heat

In contrast to the miniature solar battery is the large-scale solar furnace for high-temperature research. More than 30 of these are being used throughout the world as laboratory tools for fundamental research. Their great advantage is the ability to expose chemicals and metals to extreme temperatures (up to 3500 C) without the contamination that takes place in conventional crucibles or arc furnaces. Small 60-inch solar furnaces are used for research by a number of U.S. industries today; they are manu-

"Paddlewheel" satellite, constructed for the Air Force by Space Technology Laboratories, has four light-sensitive vanes which convert the sun's rays into useful solar energy.



Sunpower "sailboats" in space proposed by Westinghouse scientists would use the pressure of sunlight for propulsion. Having escaped the earth's atmosphere by rocket drive, the ship would unfurl its huge circular solar sails of aluminized plastic, braced by inflated fabric tubing, and sail in space on the sun's flood of radiation. Although the sunpower would be only a small fraction of a gram per square yard, the size of the "sail" area is unlimited in space. A cabin for cargo and passengers could be towed behind by a long glass-filament cable attached to the sail's gyroscopic axis.

factured commercially by Arthur D. Little Inc., J. W. Fecker Inc., and American Searchlight Co.

The temperatures of up to 5000 F which can be achieved by the largest U.S. solar furnace—at the Army's Research & Development Center at Natick, Mass.—make it possible to simulate the heat of a nuclear blast. Thus, the furnace is used in testing materials to protect troops.

In addition to their research value, solar furnaces have a practical industrial application which could amortize an installation: the production of pure chemicals such as alumina, zirconia, and thoria, and pure metals. France's Felix Trombe, of the CNRS Solar Energy Laboratory at Montlouis in the Pyrenees, has led the way. His 75-kilowatt unit now produces commercial zirconia on a regular basis for Paris firms. The new 1,000-kw unit under construction at Odeillo, near Montlouis, is expected to produce some 2,400 kilograms of zirconia per day.

Cooking without gas

Quite a few solar devices are on the market today for the domestic consumer. The Umbroiler Co., in Denver, sells an aluminized plastic umbrella-like solar cooker for about $30. The biggest market for solar cookers, however, lies not with back-yard barbecue fans, but in remote areas of undeveloped countries, or on Indian reservations in this country, where sunlight is plentiful but fuels scarce.

Some years ago the National Physical Laboratory of India made an attempt to introduce a solar cooker among villagers in that country. The attempt failed because the women would not readily accept this alteration of traditional cooking habits. Now the psychology of the people involved is studied before any attempt is made to introduce a cooker. Last year the University of Wisconsin sent two anthropologists to live on a reservation in Arizona to study reactions of the Indians to an aluminized Mylar solar cooker developed at that university's solar energy laboratory.

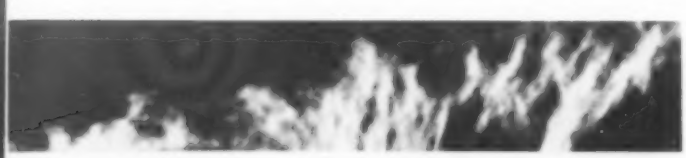
India, Burma, Israel, and other countries in the "solar belt"—from 40° N to 40° S latitude—also provide a potential market for a small (about one horsepower) solar engine of the steam-turbine or hot-air type for use in pumping water, running machinery, and generating electric power. Small steam engines of this type now cost about five times as much as comparable internal combustion engines. But if a mass market could be developed for them, sunpowered engines could be produced at less than $50 per horsepower. Intense research is needed to develop a more efficient engine, present ones being only about 2% efficient.

Large-scale production of mechanical power and electricity has been considered in solar-belt countries. In Israel, a large heliobroiler using horizontal cylindrical parabolic mirrors and capable of producing steam at 200 pounds per square inch now is under construction.

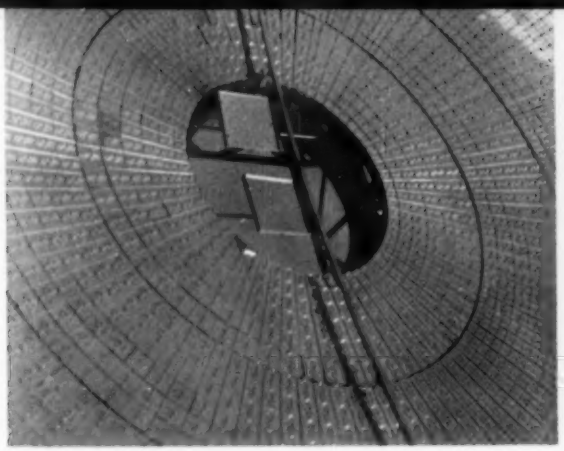
Soviet scientists have drawn up plans for a large sunpower installation for Armenia capable of producing 1,200 kilowatts. This scheme involves 1,293 mirrors, 15 square meters in size, mounted on railway carriages and rotating around a central boiler. But no word has been received on the actual construction. It may be that, like the Israeli boiler which cost four times as much as originally expected, the Soviet unit will demonstrate the present impracticability of large-scale mechanical devices.

Engineering sunpower for housing

In the United States, approximately one-third total energy consumption goes for space heating. Yet most buildings receive more than enough sunlight to supply domestic heating requirements throughout the year. It is not surprising that solar



Solar prominences 80,000 miles high are flagrant outbursts of sunpower caused by the fusion of hydrogen atoms. In three days the sun showers on earth more energy than is available from all other sources.



A giant, 40-foot sunpower concentrator on Mountlouis in the French Pyrence Mountains is part of the 75-kilowatt industrial solar furnace developed by CNRS solar energy scientist Feliz Trombe. This unit collects the sun's rays and concentrates them, generating temperatures in excess of 3000 C. Now used in the commercial production of zirconia, the solar oven also can be employed to manufacture alumina, thoria, and pure metals. This furnace is the prototype of a 1000-kilowatt model, whose daily output of zirconia is expected to be 2,400 kilograms.

heating looks good to many homeowners as a means of cutting winter fuel bills. In the past two years a number of significant experimental solar houses have been built in various sections of the country: the Massachusetts Institute of Technology house in Lexington, Mass.; the G. O. G. Löf house in Denver; the Bridges and Paxton office building in Albuquerque; the Association for Applied Solar Research house near Phoenix; and the University of Arizona solar laboratory building in Tucson.

Further research must be done, especially in developing a more efficient heat storage plant, but indications are that solar heating soon will prove commercially feasible.

Results from present experimental houses show that in areas where winters are cold and heat costs significant, a solar heating installation would cost about six times as much as a conventional system of equal capacity. But factory production of collector and storage units could reduce this figure substantially.

Maria Telkes, of New York University College of Engineering and Curtiss-Wright Corp., offers the following design criterion for a solar house: *A solar-heated house will break even economically if the installation of the system costs from two to three times as much as a conventional heating system; if it costs less it will save money over the long run.*

All solar house heating systems employ a flat-plate collector to trap sunlight and convert its energy into heated air, which then is circulated within the house. Heat is stored in water tanks, gravel beds, or chemical solutions for use at night and on cloudy days.

The MIT experiment

In the MIT house, for instance, water is employed as the storage medium for unused sunpower. Pumped through small-diameter copper tubing set in the collector which forms the south slope of the roof, the water is heated by the trapped energy of the sun. The hot water goes into a 1,500-gallon tank until the house grows cold, then is circulated through an exchanger, and the radiated heat blown through a system of ducts and registers.

A second, oil-heated tank, of only 275 gallons capacity, serves as a buffer when there is not sufficient sunpower to warm the house. It's kept at a constant temperature of at least 135 F, and can keep the entire house warm when the collector operates below a required minimum.

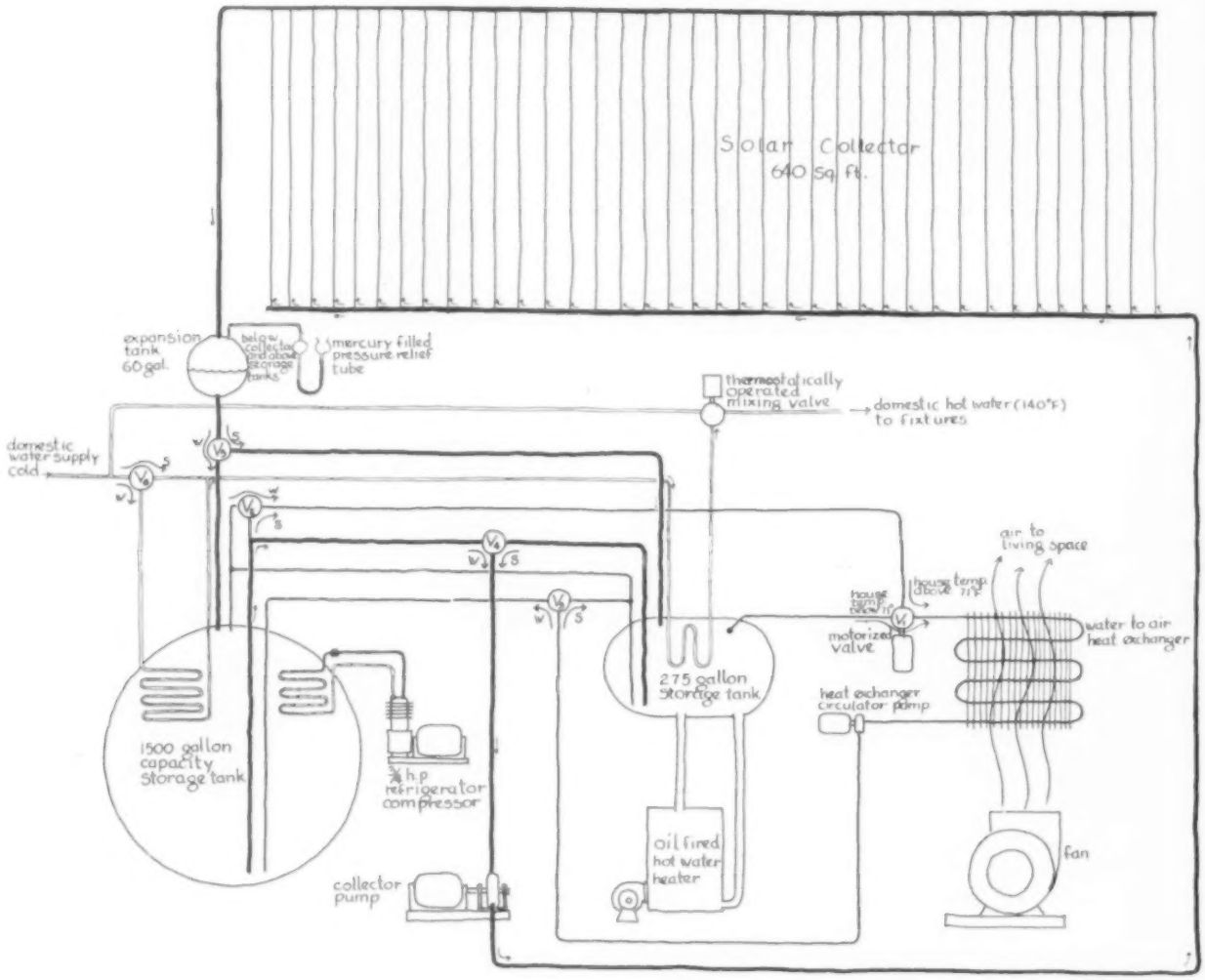
In summer the collector supplies domestic hot water. Also, a small refrigerator unit attached to the large tank pumps cooled air from the exchanger, making of it a simple air-conditioning unit. The entire system operates automatically, with the exception of several manual valves which control the seasonal shifts from heating to air-conditioning.

Solar air-conditioning

The sunny Southwest, where both cooling needs and solar energy are greatest, provides a ready market for sunpowered air-conditioning. Unlike the MIT unit, most solar cooling systems employ a volatile component, which is driven out of a solution by solar heating and condensed to a liquid under pressure. When the solution is cooled, the liquid is reabsorbed in the solution and cooling is effected by its rapid evaporation.

Ammonia-water refrigeration systems have been tested at the universities of Florida and Wisconsin. Further research and pilot tests are needed to develop equipment sufficiently economical for widespread installation, but success seems assured.

Also in the Southwest there exists a demand for



ILLUSTRATED BY M.I.T.

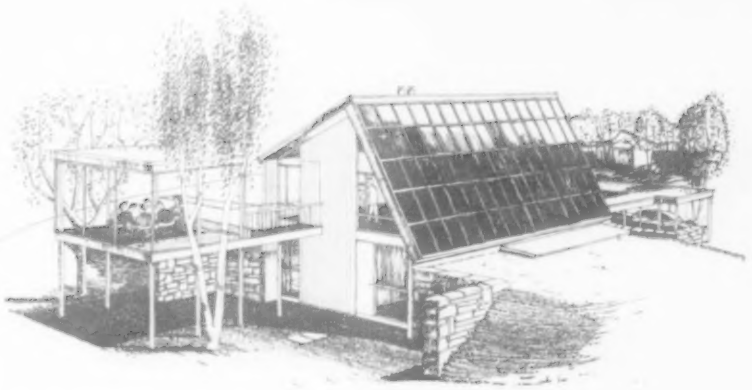
a small solar refrigerator which could be used on picnics and camping trips, or even in remote settlements where there is no other source of power.

Salt water to fresh water

Major government spending in the solar field so far has gone toward techniques for de-mineralizing seawater for drinking, irrigation, and industrial uses. Most of the work of the Office of Saline Water of the Department of the Interior has been in connection with large-scale conversion. The three experimental stills recently constructed by Battelle Memorial Institute for the OSW at Port Orange, Fla., range from 500 to 2,500 square feet. A smaller still for domestic use, selling for less than $50, has many commercial possibilities.

Some companies, while not actually producing solar devices, still benefit from advances in solar technology because they supply materials or equipment. DuPont plastics like Mylar and Teflon already

Wanted for practical solar power: (1) an inexpensive but efficient collection system;



Solar-heated house (right) was developed by scientists at Massachusetts Institute of Technology. It employs water as a medium for storing heat used after dark and during cloudy weather. A collector containing copper tubing forms the south slope of the roof, and water heated in these tubes is pumped to a basement tank (left), then into a heat exchanger and fan which fills the house with warm air. A smaller, oil-heated tank acts as a buffer against sunless weather, and in summer the unit can be converted into a solar air-conditioning system.

are finding wide use in solar space- and water-heating collectors and in solar stills.

Revere Copper & Brass, Reynolds Metals, and Olin-Mathieson all produce the metal sheets with integral tubes like those used in the MIT house. These probably will form the backbone of commercial collectors. A recent entrant in the solar field is Curtiss-Wright, which carries on a cooperative solar development program with New York University. Already selling a solar fruit drier, Curtiss has many other salable solar products under investigation.

These research achievements and commercial developments represent only the pioneering stage in the utilization of solar energy. The sun sheds upon the earth 30,000 times as much energy as we currently employ for all purposes, yet virtually none is being used.

Chief obstacle: the atmosphere

The greatest difficulties in the way of utilizing this tremendous source of power do not arise from the power source itself, but from the earth's atmosphere (suggesting more efficient extraterrestial applications):

- The sun's rays arrive on earth extremely diffused. Considerable ingenuity is required if they are to be collected in sufficient quantity and without resorting to many expensive acres of collecting units.
- Sunlight is intermittent. After the sun has set or on cloudy days, the power supply is gone, and provision must be made either to store sufficient quantities of sunpower or to supplement it with an auxiliary source.

The company that first finds solutions to these two problems—an inexpensive and efficient collection system and an inexpensive and high-capacity storage method—will be the first to realize substantial profits from solar energy.

A report by the United Nations summarizing recent developments in using various forms of nonconventional energy found that sunpower progress is such that early economic utilization may be expected. Several new developments in particular point the way to economical use.

Recent breakthroughs

The first of these is the development of new plastics and plastic combinations as a cheap substitute for glass in flat-plate collectors.

The collector is the basic unit for all sun energy conversion systems. There are two types—flat-plate and focusing. Flat-plate collectors, used in such equipment as water heaters, house heating units, and stills, consist of one or more layers of some transparent material placed over a good heat-absorbing material. They trap heat in the same way as a greenhouse. Light passes through the cover, which is transparent to shortwave radiation, and is converted to heat by the absorber inside. The heat cannot escape because the cover is opaque to longwave (heat) radiation. A new fluorinated hydrocarbon plastic film, duPont's Teslar, gives very satisfactory performance as a cover material.

The principle of the focusing collector is similar to reflectors for flashlights or automobile headlights. Until now, focusing collectors have been used only where extreme temperatures were needed (as in research, cooking, or steam generation) because of high cost. New methods of manufacturing aluminized plastic replica mirrors should result in less costly focusing devices, however.

A third development, first announced by the National Physical Laboratory of Israel, uses bodies of water as "natural" large-area sunpower collectors.

(2) a cheap, high-capacity storage method.

These solar ponds must have a black heat-absorbing bottom and some means must be found to prevent heat loss from convection, by which the heated water rises to the surface and is lost to the atmosphere. In the Israel experiments convection losses were minimized by water lavers of varying density, produced by the addition of various salts. Under sunlight conditions prevailing in Israel, a square-kilometer pond could (at a collection efficiency of 2½%), produce 50-million kilowatt hours of electricity.

The Israel laboratory also has pioneered in developing "selective surfaces," although a number of research groups in this country, notably those at MIT, University of Wisconsin, and University of Florida, also have been active. Selective surfaces are thin black coatings of a semiconductor deposited on a bright metallic surface; they absorb most of the incident sunlight and emit only a small fraction of infrared (heat) radiation.

Heat to electricity – direct route

Solar energy can be converted to electricity without the use of an intermediary heat engine—with consequent reduction in capital investment and operating costs—by thermoelectric or photoelectric converters. Important advances have been made in recent years, and the use of semiconductor materials has increased their efficiency greatly.

Photoelectric batteries used in satellites, portable radios, and most other applications now employ silicon cells, but cheaper semiconducting materials soon may prove feasible. Meanwhile, steady progress has been made in reducing the price of standard silicon cells.

At the time of the First World Symposium on Applied Solar Energy in 1955, thermoelectricity was not seriously considered as a possible converter of sunpower because of its low efficiency and because expensive, nonpermanent materials had to be used. Recent developments at Westinghouse, in the USSR, and elsewhere, indicate that less expensive materials in the form of semiconductors of mixed compounds can be used effectively as thermocouples.

Another remarkable advance is the thermionic converter—a high-powered evacuated thermionic diode that produces a flow of electrons from a heated cathode to a cooled anode. These converters give efficiencies up to 12%, but require parabolic mirrors to produce the high temperatures.

The future: dollars = progress

The state-of-the-art of utilizing sunpower has advanced to the point where widespread commercial application is almost directly related to the funds that are obtainable for R&D. Pending before Congress are bills calling for $10 million to launch a solar energy research program. Yet, even if solar research does receive greater government support, there is still much room for private business to exploit this limitless source.

The conventional fuels that have supported our growing energy requirements since the Industrial Revolution will not last more than 100 years at the present rate of depletion. Soon there will be an acute need for supplementary sources of power.

Whether or not we find ways to utilize atomic energy economically and practically in large and medium-sized cities, there still will be many areas of low-energy-demand density where sunpower can have a techno-economic advantage. It will be a complement rather than a competitor in helping supply world energy demands. It is possible that sunpower will satisfy as much as 40% of the total energy requirements in the year 2060.

The main prerequisite is R&D, a century earlier. ■

A nuclear physicist, Dr. Leonard Reiffel is director of the physics research department at Armour Research Foundation of Illinois Institute of Technology. As such, he heads a staff of 115 scientists—one of the largest independent physics groups in the U.S. He participated in the first hydrogen and atom bomb experiments in the Pacific and later helped establish, at Armour, the first nuclear reactor for industrial research. A member of the Atomic Energy Commission advisory committee on radioisotopes, Reiffel has attended several international nuclear conferences, including the recent Warsaw radiation conference described in this article. Prior to joining ARF in 1949, he was associated with Dr. H. L. Anderson and Prof. Enrico Fermi at the University of Chicago's Institute for Nuclear Studies. Reiffel, who holds several patents on applications of radiation energy, received his PhD from Illinois Institute of Technology in 1953.

by **Dr. Leonard Reiffel,** *director of physics, Armour Research Foundation*

a new look at

NUCLEAR RADIATION ENERGY

ONLY RARELY DOES MANKIND have to deal with a new form of energy. Optimism and pessimism alternate in the early history of any discovery or invention, but surely a most spectacular example is one we now are confronting—nuclear energy, both as a source of heat and electricity and in the form of high-energy penetrating radiation.

At first nuclear power was going to supply electricity and heat so cheaply that energy would be "free"—thus at least completely revolutionizing civilization. Such predictions came shortly after chain-reacting piles proved workable. Some 10 years later, a spirit of gloom settled over American Nuclear Society meetings whenever the prospect of developing competitive nuclear power was discussed.

Currently, as more and more power reactor prototype data become available, costs for electricity from the atom seem to be edging down below 10 mils per kilowatt-hour, toward perhaps seven mils per kilowatt-hour—not the cheapest form of power on earth, certainly not free, but economically important and someday, perhaps, the very basis of civilization. We now seem to have re-climbed part way up the optimistic side of the cycle.

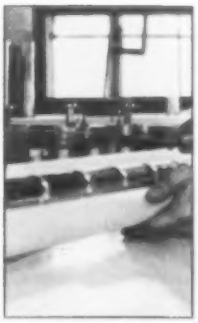
We are moving through a similar cycle with high-energy radiations for industrial processes. However, we are not so far along, having gone through only one full cycle, rather than the one and a half cycles of power production.

A few years ago the obvious fact that a civilization based on nuclear power would be producing huge quantities of radioactive materials led to the desire to use radiation, for example, as a processing tool. In fact, by simply multipling numbers to decide how many million curies of radioactive fission products will be available, you can present a fairly convincing argument that radiation from such materials ought to have enormous industrial potential.

As a result there were many people who felt that a new age of processing with radiation was about to dawn along with the advent of nuclear power. Serious research programs were started by a number of companies, especially in the petroleum industry (for example, at Esso Standard Oil Co., Shell Development Co.), and in food (Swift & Co.) and pharmaceutical areas (Lilly & Co., Abbott Laboratories). In general, these programs and many others like them have not yet produced results of great economic impact, at least as far as making irradiation the key step in a production process.

On the other hand, no one would argue that radioisotopes and radiation energy have not been of enormous benefit in research, especially in medical and biological research, as well as in the physical sciences and engineering.

The special case of radiation processed food has been discussed so many times and in so many places that I hesitate to bring it up again. Yet, radiation processing of food at both the pasteurization and sterilization levels has been demonstrated successfully, the former requiring a dose of about one-million rads while the latter requires about five million rads.



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1 *Small cans of food are placed in a plastic spacer for exposure to Argonne's gamma radiation facility.*

2 *Armour Research Foundation physicists set up a beam experiment to check radiation levels and stray nuclear radiation.*

3,4 *A remote control device, Nuclear-Chicago's remote pipette, carries a strontium-90-chloride solution from one vial to another in a syringe-type device. The solution will be purified and processed into high intensity sources for industrial gaging and medical studies.*

5–7 *At Argonne's gamma facility avocados are preserved by irradiation. They are placed in a cylinder for exposure (5), quickly removed from the source for strict control (6), and then removed from the cylinder (7).*

8 *Argonne's facility uses spent reactor fuel elements clustered around a rack. Position of the rack varies radiation levels, while water shields technicians from radiation danger.*

(A thousand rads corresponds to the absorption of 4.56 watts-seconds of radiation energy per pound.) At still lower levels, on a laboratory scale, radiation has successfully de-infested and inhibited biological changes in food, such as the sprouting of potatoes in storage.

Implicit in all of these food applications is the possibility of a real revolution. Even the rather mundane application of anti-sprouting treatments is quite significant in certain areas of the world—bringing promise of important simplifications in marketing and distribution problems.

Long shelf-storage of foods now requiring careful refrigeration would have overwhelming effects not only in a technologically advanced country such as the United States, but particularly in underdeveloped countries of the world where refrigerated storage is uncommon. The implications of a fully developed radiation preservation technology would reach down to the very roots of the world's economic, political, and social structure.

Research leading to this laudible objective is proceeding apace in the United States, the USSR, England, and France. Recently, in the U.S., technical questions centering on the remote possibility of induced radioactivity and on uncertainties in the definition of a sterilizing dose of radiation have become almost inextricably interwoven with the process of political decision-making. The resulting confusion undoubtedly has slowed the program's technical progress as the moment of public use of radiation sterilized foods approaches.

European nuclear facilities

France, moving rapidly in this area, has under construction a unique pilot-plant irradiation facility using the spent fuel elements of a nuclear reactor. It is being built collaboratively by the French government and a large number of industries. Many relatively small-scale facilities exist using spent fuel elements for their radiation sources, but almost all of these rely upon water for both shielding and cooling, thus implying that anything to be irradiated must be submerged. The French facility, however, incorporates concrete shielding, thus allowing irradiation of material in the open air.

Britain has produced several small-scale irradiation facilities to study food processing and to explore other possibilities.

Recently the British have shipped a large amount of radioactive cobalt, at very low cost, to Australia, where it will be used for full-scale sterilization of goat hair against anthrax.

In the USSR, a healthy program of source development is progressing and the construction of a potato irradiator for sprouting inhibition is underway. It had been thought in the West that this radiation facility was already in operation, but recent conversations with Russian scientists, at the first conference of the new International Atomic Energy Agency in Warsaw, have made it clear that it is still under construction.

Incidentally, it is an open question as to whether irradiating potatoes is promising. Early U.S. results indicated it was. Later repetition indicated that under actual field conditions potatoes were bruised and the radiation prevented healing of the bruises, actually inducing more harm than good. However, British work, done with a rather low dose of 15,000 roentgens, as compared to the U.S. studies with 25,000 to 50,000 roentgens, did not encounter this problem.

Here, as well as in many other areas of radiation processing, there are differences between results in the laboratory and those obtained in actual practice as a result of handling procedures. While it is clear that radiation processing of food has a great potential well worth pursuing, refrigerators still are going to be around for some time to come.

Radiation for new chemicals unnecessary

All examples have dealt with a substance to be treated in its final form—for example, a potato, lamb chop, or a loaf of bread. The power of high-energy penetrating radiations to "get into" a substance without destroying its physical structure is perhaps the most unique factor of radiation processing—it can treat the inside of something without the intrusion of any physical object. Thus, you can vulcanize tires after the rubber has been put into its final shape (as has been done by Firestone) or you can sterilize medical products such as sutures or salvaged portions of human bodies.

But when radiation is applied to make new chemicals where the object's *macroscopic* shape is of no significance, the situation is vastly different. Here the penetrating power of radiation is perhaps a convenience rather than a necessity. In fact, for some thin film irradiations (for example, American Machine and Foundry work on permionic membranes) the penetrating power is actually a nuisance. In such cases, medium energy accelerators can be considered as non-nuclear sources of moderately penetrating electrons.

Accelerator manufacturers like General Electric, High Voltage Engineering, Dynatron, etc. also are working on the production of simplified and reliable high-energy machines to produce intense beams of electrons carrying many kilowatts of beam power. The penetrating power of these machines promises to be sufficient to treat at least certain types of prefabricated structures. In fact, the competition between accelerator and radioactive sources of high-energy radiation is extremely intense today.

Competition from the conventional

There is a strong likelihood of a different competition which has not yet developed very clearly and has

THE CONSENSUS *at the international conference on radiation held in Warsaw in September, 1959 (titled "Application of Large Radiation Sources in Industry and Especially the Chemical Processes") supports the position taken here by Dr. Reiffel, who attended the conference.*

That is, ionizing radiation has not yet become an industrial tool of major importance largely because it cannot compete economically with present non-radiation processes.

A comprehensive report on the subject by A. D. Little Inc. suggests that although potential applications of radioactive nuclide sources have been under study for 10 years, the scoreboard shows few important breakthroughs. Two processes are currently in production; 10 are in various stages of process development; and some 20 to 60 others are undergoing active laboratory research.

Present routine uses of nuclides are in the sterilization of sutures for surgical operations and polyethylene cross-linking for increased strength at higher temperatures. Other small-volume specialties once marketed but since discontinued: irradiated plastic ball-point pen cartridges, sterilized plastic bottles, and opthalmic ointments.

Products and processes already under development are primarily in high-cost areas like plastics, petrochemical synthesis, and sterilization. Most are still confidential, but one is known to be a semipermeable membrane for use in the electrodialysis of water. Considering these and the 20 to 60 processes still in the laboratories, only one or two new applications of radiation can be expected to appear on the market each year for the next few years (barring major research breakthroughs).

The report estimates present-day radiation production costs (with slight variations for electron accelerators, cobalt-60, and cesium-137 sources) at $10 per kilowatt hour for three-kilowatt installations, $3/kwh for 30-kw installations. It is conceivable that this figure could be reduced within the next five years to somewhere around 10¢/kwh using present-day technology, if sources of megawatt power could be utilized.

Assuming that such "cheap" radiation became available, several industries probably would benefit from closer study of high-power sources. Phenol and vulcanized rubber and certain petroleum-refining processes have the potential, if not the proven ability, of using these megawatt levels profitably.

The major competition exists between all types of

Market expansion of processes which now are more expensive also might make good use of the cheaper higher-powered sources and take advantage of reduced overall savings. For example, polymers used in the manufacture of lubricant additives and detergents (presently in small-volume production) might be potentials for cheap radiation application if some way could be found to increase sales.

To complete its survey of present and potential applications of ionizing radiation, A.D. Little queried experts in major industries known to be studying radiation:

- Petroleum: *Use of radiation in refining is not forseen at least until it is brought down to the cents-per-kilowatt hour level or until some unique feature it possesses is discovered. Alkylation probably will be the area of first application of lower-cost radiation processes.*
- Chemicals: *Ionizing radiation frequently is nonspecific in its effect, hence must compete economically with other, less direct chemical means to the same end. Thus, heat, pressure, and catalysts can supply activation energy; ultraviolet light, electrical discharges, and peroxides can free radicals and produce other excited species. So far, extensive application of radiation has not been warranted economically.*
- Polymers: *Most applications now in the development stage are in this area. Cross-linking is in current use and graft- and co-polymerization are good prospects for realization soon. Irradiated polymers often are quite different from conventional ones, and while other processes exist which will achieve the same effects, the small amounts of radiation involved makes it competitive.*
- Medical supplies and pharmaceuticals: *Sterilization in these fields already has proven commercially practical because of the unique qualities of radiation processing.*

Major roadblocks in the way of economical utilization of ionizing radiation today is the lack of basic research: we know too little about the fundamental interaction of radiation and matter.

More than $10-million probably is being spent each year to explore radiation, but a large percentage still is consumed in wasteful trial-and-error. Several companies have abandoned research. Hopefully, several others have begun fundamental, long-range programs. The state of the art can be summed up by saying it will be necessary to begin again at the beginning. ■

not been fully recognized—the competition between high-energy radiation generally (be it from reactors, isotopes, or accelerators) and other processing means either known or still undiscovered. When irradiation in final physical form is not crucial, this competition should be especially severe. The point is that—once we discover a radiation technique for producing a substance the macroscopic form of which is not important—there will be a substantial reward waiting for someone who finds the way to do the same thing without the use of radiation.

The reason: simply that radiation is, and probably will continue to be, fairly expensive.

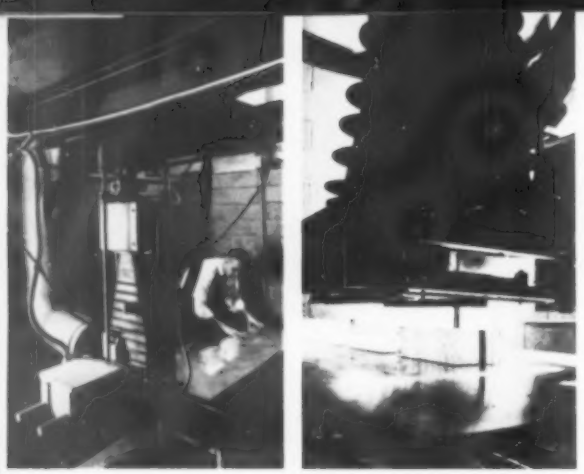
So if excited states or free radicals are needed, for example, and radiation can produce them, industry immediately will look for chemical, electrical, or optical means to do the same, and the *real* drive to replace radiation in such cases will not develop until a radiation process appears potentially profitable.

On the other hand, even without this conscious effort to replace radiation, it has been extremely difficult to find potentially interesting processes where radiation is not replaceable even *a priori* by other methods. The CEM group (Chemical, Electrical, Metallurgical) comprised of General Aniline & Dye Corp., Emerson Radio Corp., and Revere Copper & Brass Inc., recently has completed an attempt to evaluate the use of massive radiation in industrial processes. Of the many possibilities, the group has pointed out several which appear to be worth pursuing. But these few will require considerable development, and competitive processes not requiring high-energy radiation may also be developed for the same purposes.

What does 'free' radiation cost?

One situation which clouds the issue involves reactors as radiation sources when these reactors are

high-energy radiation and other processing means either known or undiscovered.



General Electric Co.'s 2-million-volt electron beam generator is used in a test at GE's Coolidge lab, Milwaukee, to find a better-performing plastic through irradiation. Electrons, emitted from a heated tungsten filament of the cathode, are accelerated almost to the speed of light by high-voltage electrons in a permanently evacuated, multi-section electron-beam tube. Magnetic fields focus the beam and electrons emerge from a thin window at the end of the tube, colliding with the material's own electrons, thus causing ionization. Such electron radiation sources can be used to produce crosslinking, polymerization, vulcanization, degradation, oxidation, reduction, inhibition, sterilization, deinfestation, and similar changes in materials.

built primarily as electrical power producers. The radiation is "free," so to speak.

The question then becomes: will the handling procedures and other costs relating to the special requirements of processing in a nuclear reactor be greater or less than the expense of other non-radiation processes?

Certainly a concerted R & D effort is justified, as is the requisite pilot-plant effort which should follow. But it would be foolhardy to lose sight of the possibilities of developing alternatives to these processes with the expenditure of an amount of money comparable to that required for development of a radiation process itself.

It is impossible to predict whether radiation ever will become an irreplaceable and economical method of process stream production. We must find out, by means of a vigorous and broadly-based research program. Conversely, it is certain that radiation treatment with pre-formed objects will continue to promise truly unique results.

Another kind of nuclear radiation energy of industrial importance is the radioisotope source used in process control and monitoring equipment. A number of known and widely advertised applications already exist and have resulted in substantial economies. Outstanding among these certainly are the beta-ray thickness gage, level gages, and tracer techniques for mechanical wear studies.

Our guessed-at savings

It is difficult to estimate the real economic impact of these techniques, especially when the list includes such specialized applications as pipe-line flow interface marking, flow-rate measurements, moisture measurements, coal inventory techniques, and so on.

The great versatility of radiation and radioactive materials, not as a primary form of energy for processing, but rather in a control and measuring role, makes the task of assembling realistic numbers as to worth extraordinarily difficult. In testimony to this fact is the wide range of estimates which have appeared. An Atomic Energy Commission study suggested annual savings to U.S. industry in 1958 might be as much as $392 million. Yet, a National Industrial Conference Board survey, sponsored by the AEC, recently reported a figure of $39 million. The truth, if truth has any real meaning in this situation, probably lies somewhere between these two figures.

In any event, it is obvious that radiation and radioisotopes have enormous promise as helpmates to industry even if they do not develop into a major source of energy in a special form for industry. The subtleties of the possibilities in this former role are such that it is difficult for anyone in an industrial organization to justify expenditure of large amounts of R&D money on a specific application. Still, the overall strengthening of the economy which can result from bringing to fruition the various techniques relying on radiation and radioisotopes can be most important if integrated over the entire industrial complex of the U.S.

In recognition of this situation the AEC has begun to provide funds for the development of radiation and radioactivity in industry. The program, which spreads over a wide range of industries and through almost every scientific discipline, will shed light on the importance of high-energy radiation to the national and global economy.

In the meantime, the scientific community has an obligation to dampen oscillating opinions and to answer the basic questions of nuclear energy as a power producer and as a special form of energy for industrial use. Only with this knowledge will the United States be able to pursue a course leading to the strongest ultimate technical and economic position. ■

CAST OF CHARACTERS

R/Adm. J. T. Hayward, *assistant chief of naval operations (R&D)*
Hon. Gerald R. Ford Jr., *Republican, Michigan*
Hon. William E. Minshall, *Republican, Ohio*
Hon. Daniel J. Flood, *Democrat, Pennsylvania*
Hon. Charles A. Boyle, *Democrat, Illinois*

OUR NUCLEAR SEAPLANE

CERTAINLY, one of the more startling uses of man's newly acquired nuclear energy is for propulsion. First applied to submarines and ships, atomic railroads and aircraft also have been proposed. Often the merits of these "proposals" wind up in Congressional hearings—dramas of our time as vital and interesting as the product of a playwright. The following "play" is excerpted from a House appropriations subcommittee testimony on Department of Defense spending for 1960.

Which comes first: the aerodynamics expert?

REP. FORD

REP. MINSHALL

MR. FORD: You mentioned in your presentation something about a nuclear-powered aircraft. What is the Navy doing in this field? How much is being proposed in the R&D budget for 1960? What progress are you making? Just what is the situation?

ADM. HAYWARD: This has been a long, difficult program, Mr. Ford. I probably have been one of the outstanding critics of it. To my way of thinking it's a monument to how not to run a technical program. Some $853 million has been spent on changing concepts that have been false and unattainable. It's still a poor program with little hope at present from my point of view. We have taken the approach that we want a relatively low-powered long-endurance seaplane for logistic purposes as well as ASW (Anti-Submarine Warfare) and AEW (Anti-Electronics Warfare) purposes.

MR. FORD: This is the Navy's program?

ADM. HAYWARD: Yes, sir. To give you some history on it, last Spring the Joint Committee requested that we present what we thought on this program, which we did. Then we were asked to recommend a national nuclear-powered aircraft program to the Joint Committee. We recommended a program. (*Discussion off the record.*)

MR. MINSHALL: (*Glances at wristwatch.*) What are the Princess boats?

ADM. HAYWARD: They're built by Saunders-Roe in Britain. They are seaplanes of 300-some-odd thousand pounds gross weight. We proposed this as a national program to the secretary of defense. We didn't believe in the approach that had been taken. I never have believed in it technically. It was turned down by the Department of Defense. The Navy wouldn't support it on our own funds. We didn't have sufficient funds to support it. I also felt that, while the military potential was great, I would be the last one to get up and say this is the system to end all systems.

MR. FORD: In the alternative, did the Air Force submit a program?

ADM. HAYWARD: Yes, sir.

MR. FORD: Is that the one being funded by the Air Force in its R&D budget?

ADM. HAYWARD: Yes, sir. There is $150 million for this program in the present budget. They came in with a proposal for the Camel system, they call it, which is continual patrol by nuclear airplane capable of launching ballistic missiles. This would be the same, in my opinion, as if Adm. Rickover has said that we would put the *Polaris* in the *Nautilus* submarine. (*Chuckles.*)

The fundamental truth about the nuclear propulsion business is that we don't have a successful fuel element. I've compared the total sum spent to date with what we have spent in the Navy. For the same sum of money in Adm. Rickover's program we have done all of the research and development, paid for all the fuel costs, built all the facilities, built the prototypes, and delivered three operational submarines to the fleet for the same cost.

Of course, I attribute this directly to Adm. Rickover's position that he was going to get an engine before he got any sort of system.

The program has suffered from a changing concept. When it was envisioned first, everybody wanted a nuclear bomber that went at mach 3. Any physicist could have told you that the radiation and temperature problems were insurmountable at that time and for many years to come. So it has gone back and forth over the years.

I feel the indirect cycle has application to the Navy's use in the low-power field: 60 megawatts to 100 megawatts, in the turboprop version for logistics and for ASW and AEW. We put $2 million in the 1959 program which had been impounded. I insisted that we put this at the Pratt & Whitney plant in the development of liquid systems, cooling, radiators, and components.

Our total effort in 1961 will be roughly about $4 or $5 million, but primarily in the components of the system and in trying to get a turboprop engine married to a reactor. Until you get the components made, you aren't going to get an overall system. This has been the Navy's position.

MR. FORD: The Navy's program, then, is proceeding independently of the Air Force program.

The government can have its nuclear seaplane by 1964 if it is willing to spend the

. . . or the nuclear physicist?

ADM. HAYWARD

REP. BOYLE

REP. FLOOD

ADM. HAYWARD: No, sir. We wrote a letter to the secretary of defense, who also wrote to the Atomic Energy Commission and the *Canal* facility up in Connecticut, which is an Air Force facility operated by the Atomic Energy Commission. We are allied closely with the Air Force, which is interested in the liquid metal cycle also.

However, it is further away. And the Air Force has the direct-air cycle—that big engine out at G. E. —and something has to be done with it. We don't believe in a direct-air cycle. It has some very fundamental drawbacks to our problem, using the divided shield instead of the unit shield, and exposing all our equipment to radiation. We just cannot live with it.

MR. FLOOD: Will the gentleman yield? I am wondering, what is the important thing in nuclear propulsion for air—experts in nuclear engines and propulsion, or experts in aerodynamics? Which comes first, the chicken or the egg?

ADM. HAYWARD: In this particular case, an airplane needs an engine, and in order to get an engine you need materials—high-temperature materials. You need materials that will last at 3,000°, for instance, for long periods of time.

MR. FLOOD: If the gentleman will yield further, that is the question. It is no answer. My question was, (*Twirls moustache.*) what do you need first, the engine? Do you need an expert in nuclear propulsion and nuclear mechanics, or do you need first an expert in aerodynamics?

ADM. HAYWARD: You need the nuclear propulsion. You do not need the expert in aerodynamics. He is the least of the problem.

MR. FLOOD: (*Removes glasses.*) If the gentleman will yield further, in what is Adm. Rickover an expert?

ADM. HAYWARD: Nuclear propulsion.

MR. FLOOD: Then why don't you have him figure out nuclear propulsion for an aircraft?

ADM. HAYWARD: (*Smiles patiently.*) Mr. Flood, he has 33 ships. We have plenty to do in the ship business. The last person I want to get mixed up in taking over the job is Adm. Rickover.

MR. FLOOD: I asked the Air Force that, and they said they would take him tomorrow morning and be glad to have him.

ADM. HAYWARD: I am not so sure.

MR. FLOOD: (*Sits up stiffly, replaces glasses.*) I am telling you what they told me.

ADM. HAYWARD: It would be an excellent idea.

MR. FLOOD: If he did as much for the Air Force as he did for the Navy, I hope he goes tonight.

ADM. HAYWARD: I do not want to say that aircraft nuclear propulsion is the end-all in military systems. It has great military potential.

MR. FLOOD: Nobody suggests that it is.

ADM. HAYWARD: I do not want to give Adm. Rickover away, Mr. Flood. We need him.

MR. FLOOD: No. I am trying to give him to the air arm of the Navy, which seems to be bogged down in nuclear propulsion hardware. This man seems to be more than a black-shoe sailor. If first things come first, it is how do you push that crate? I don't care what kind of crate it is—whether it's a ship in the air or a ship in the water. If this character Rickover can push it on and under the water, as far as I'm concerned he can push it through the air.

MR. FORD: What is your forecast, Adm. Hayward, as to when you'll have an operational aircraft in this area?

money now.

ADM. HAYWARD: By 1964. It could be done sooner in the national program I propose, if somebody wanted to do it just to get it in the air for psychological reasons. You could get it in the air in a different way. You wouldn't have to use direct-air cycle in the seaplane.

My proposal was that we go ahead and do that, and if we wanted to put *U. S. Air Force* on the seaplane, that was fine by us. We didn't want to argue about who was going to make the first flight. So we're engaged in an orderly R&D program of materials, components, and engine development. By 1964 we should be able to put a seaplane in the air.

MR. FORD: You will then have a prototype that will have some practical application from a military point of view?

ADM. HAYWARD: It will be a test-bed, Mr. Ford; it will not be a system. We will determine then whether we would go to a system. You see, this is where we get into large costs by saying right away we'll go to a system. This is where I disagree with the proposal of making a Camel system: for instance, of having an air-launched ballistic missile from a nuclear airplane. You haven't a nuclear engine, let alone the missile or the airplane. It's a billion-dollar decision, practically. I don't want to make that until I've done my homework and the component work.

MR. BOYLE: Will you likewise supply the total amount of your request to the budget authorities?

ADM. HAYWARD: Yes. The total request was $4 million. In the fiscal 1960 program, $2 million. Total expended fiscal year 1955-59 was $12.4 million.

MR. BOYLE: Like my colleague, Melvin Price, of Illinois, I am very much concerned about the progress of the nuclear-propelled airplane. I don't feel we should indulge in sour-grapes rationalization regarding our loss to the Russians on that bird at this time. Don't you feel, in connection with your concept of Fortress America, that there is a crying need for that piece of hardware?

ADM. HAYWARD: Mr. Boyle, it has great military potential. From the Navy's requirements and point of view, we feel we can get it out of a nuclear propulsion system of low power for seaplanes.

MR. BOYLE: Tell me, is it a question of money? If you had more money, could you accelerate the program?

ADM. HAYWARD: Certainly, Mr. Boyle, we could accelerate the program, to a degree.

MR. BOYLE: Is it your opinion that you want to give to the committee the impression that you don't feel the amount involved is worth spending at this particular time?

ADM. HAYWARD: It is worth spending, yes.

MR. BOYLE: Have you had any notion about the kind of money we are talking about?

ADM. HAYWARD: Yes. The national program we proposed to the secretary of defense actually to fly this aircraft—this seaplane that was given to us—was roughly $220 million. We would have it in the air in 1962 or 1963.

MR. BOYLE: That might be the primary use of the bird, but it would not necessarily be the exclusive use. It would be available probably for other types of aircraft, would it not?

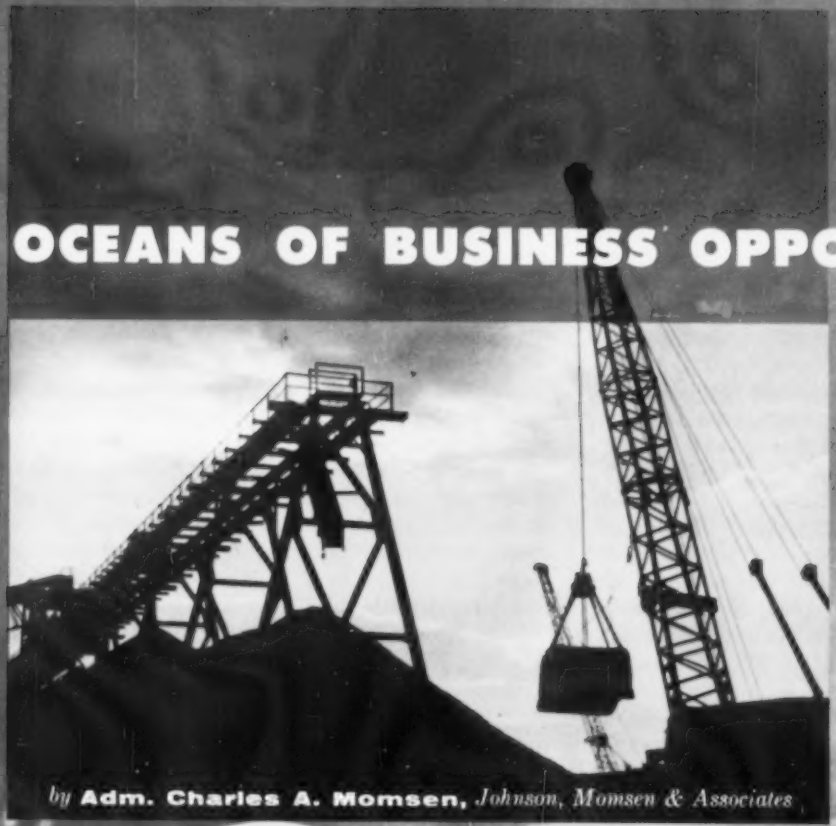
ADM. HAYWARD: That is correct. It would be nothing but a seaplane as an engine test-bed to get a powerplant for the ultimate system. This is one way to get something in the air if the Joint Committee wanted to get it in the air from a psychological point of view.

MR. BOYLE: And by that term you appreciate its terrific impact over the entire world?

ADM. HAYWARD: That is correct. We learned that the hard way with the *Vanguard* business and the IGY. It has the same application.

MR. BOYLE: Let the record show at this point that I, for one, am very unhappy with the progress made in this area. It appears we are penny-wise and pound-foolish not to do something before the Soviets get a piece of this military hardware operational. ■

OCEANS OF BUSINESS OPPORTUNITIES



by **Adm. Charles A. Momsen,** *Johnson, Momsen & Associates*

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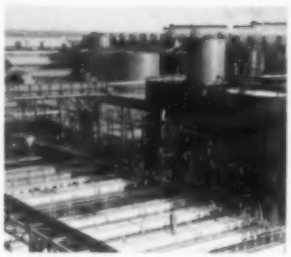

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CAN IT BE that, as with Sputnik which triggered an hysterical effort on our part to catch up in the space race, we have been awakened to the urgency of greater study of the oceans by reports of Russian advances in oceanography? Or are frequent warnings of scientists that our hydrocarbon fuel supply is dwindling and food production inadequate to meet anticipated demands finally achieving some results in the laboratories and factories of industry?

Whatever the cause, the effects upon business and the military will be far-reaching. Present research in commercial exploitation of oceanic resources soon may lead to a significant source of power, food, and minerals—literally "oceans" of profit opportunities.

It is the "interface," that area "between wind and water," that man knows best, and for centuries he has plied it with his vessels, battled its vastness, and finally subdued it. Still the sea is one of the most incommodious roads he could have chosen to travel. Its surface boils with continuous motion, driven by winds, currents, and tides. At last, with technological progress, the magnitude of these forces can be reckoned, and put to do a share of man's work.

Harnessing seapower

Out of the Passamaquoddy project, for example, getting underway in the tidal waters between Maine and New Brunswick, scientists soon hope to realize a dream of two generations—profitable utilization of these great, 25-foot tides in driving turbines for hydroelectric power.

By damming the Passamaquoddy and partially controlling its flow, they will use the tidal rush of these waters to advantage and in the lull between flood and ebb, introduce the flow of the St. John River to provide continuous power.

Cost is a major deterrent, but once constructed, Passamaquoddy should provide upwards of 575-million kilowatt-hours of firm, steady power in a year, enough to make the undertaking worthwhile. "Experiment" is all it ever will be, however, as the utilization of about a half-dozen world-wide sites equally suitable for power generation would provide only 0.2% of current power consumption.

As tidal projects like Passamaquoddy will be located primarily along rocky northern coasts, engineers are giving increasing attention to another purely regional characteristic—this time tropical. Surface temperatures in the tropic seas measure as much as 85 F, while the water 265 fathoms down stays at a constant 44 F. This temperature difference has been used successfully to drive turbines.

The French are considering an installation in Abidjan, West Africa, to make use of the fact that reduced pressure yields lower boiling points. Water at surface temperature would be turned to steam under reduced pressure, driven through turbines, and condensed and cooled by water pumped from below. It is thought that such a generator would use only about one-eighth of its power to drive its own internal system. Some 20,000 miles of ocean shoreline are adaptable to this condenser system, and all are in fuel-scarce regions.

Seawater, man's richest lode

Dissolved salts and floating minerals, part of them from industrial dumping, increase the average specific gravity of seawater. In effect, seawater is an extremely productive vein of minerals—40 of them in all—waiting for man to find ways of mining it.

Estimates of the amount of chemicals available range up to 150-million tons per cubic mile of seawater. Sodium chloride, of course, predominates, consitituting some 85% of the total. Other than magnesium, also quite plentiful (3½%), iron, manganese, zinc, lead, silver, and gold occur in small but

Magnesium hydroxide is formed from oyster shells at a Dow Chemical Co. Texas plant. The shells are dredged from the Gulf of Mexico (1), roasted into lime and mixed with fresh water (photo right), then mixed with sea water in a flocculating tank (2). A filtration and evaporation process (3) concentrates the slurry mixture which is drawn from the bottom of a settling tank (4). Hydrochloric acid neutralizes the magnesium hydroxide to produce magnesium chloride. Further purification, concentration, and separation yield molten magnesium of almost 100 per cent purity.

significant quantities. Various salts besides sodium choloride, including sodium phosphate, potassium choloride, and magnesium chloride, are also distilled from seawater.

Mining seawater by distillation leaves no useless remainder. Chief byproduct of the process, of course, is fresh water, a significant industrial material itself. Pilot plants to study seawater conversion on a large scale are being built under government contract.

If a systematic breakdown can be devised which will separate salts from fresh water and in turn use them, every ounce of seawater can be employed profitably.

There's gold in them there waters

Not the least among these riches is gold—$90-million worth in every cubic mile—if a way can be found to extract it. Many serious efforts have been made in the last century or so, but so far they have succeeded only at the cost of several dollars for every dollar of gold extracted. Ordinarily insoluble, gold will flake so finely that it actually floats. But certain elements, among them chlorine and bromine, readily form gold compounds.

One method which holds some promise for the profitable extraction of gold, as well as aluminum and uranium, is Armour & Co.'s recently-patented "soap and bubble" process. Bubbles of selected soaps "chase" minerals to the surface as they rise, and the scum which results can be collected and processed. Prof. Felix Sebba, of Johannesburg, who developed the process, estimates that one operation could recover 600 tons of aluminum, two tons of uranium, or 240 ounces of gold daily from the sea.

Bromine and magnesium are the real treasures of the ocean today. A scarcity of bromine was created in the late '20s with the development of anti-knock additives for gasoline. The Ethyl-Dow Chemical Co. set up a plant to recover bromine from unevaporated seawater (they occur in a ratio of one pound to one ton), which by 1938 had achieved a yearly production of 20,000 tons. Ethyl-Dow has added another plant since, and remains the only private producer of bromine from the sea.

Dow pioneered in magnesium recovery, too, and produced some 40,000 tons a year during World War II. Today all of our domestic magnesium and at least 80% of our bromine comes from the sea. As mining the oceans becomes profitable, new seawater facilities are being established. Two magnesia plants are planned for the Gulf Coast by the H. K. Porter Co. of Pittsburgh and Michigan Chemical Corp. of St. Louis, Mich. New processes, the result of increased R&D, also are being developed, and ion-exchange resins and chromatographic absorption soon may find commercial application in seawater recovery. They remove salts from water rather than water from salts, at a great saving in power.

As man's landlocked mineral resources begin to fail him, research in the mining of seawater will become more than academic, and development will become imperative. Another area of proven profit lies just beneath this watery wealth—the ocean bottom, deep in the sediment of centuries, rich with the accretion of the seas.

The "pantry" shelf

A relatively shallow shelf of land surrounds each of the continents, projecting out into the ocean and separating shore from deep water. This continental shelf is a treasurehouse of animal and mineral wealth—a "pantry" shelf of good things ready for the taking:

- Its soil is some of the earth's finest, washed down river valleys.
- It is rich in minerals leeched from the land by flowing water.

Undersea research vehicles will chart the topography of the ocean floor for use in submarine navigation, and explore the ocean's rich mineral and oil deposits. Present bathyscaphs can descend more than two miles, but several improved vehicles have been proposed. Reynolds Metals Co. plans an aluminum research submarine for three-mile descents, the Navy is designing a sub with a seven-mile capacity, and Stanford Research Institute is studying submerged nuclear-powered research laboratories for the AEC. Structural problems present the greatest barrier to descending beyond the present two-mile limit. If research subs could withstand pressures three miles down, 95% of the sea's floor could be explored.

■ Its plant life sustains the oceans' inhabitants and could support man himself.

No one knows how deep the sediment lies on the ocean floor; we have measured as much as 3,000 feet. All of it is rich and fertile, fed by erosion and organic decay, saturated with the mineral wealth of seawater, awaiting what can be a very profitable return to dry land.

Just as these nutrients can be used to fertilize a farmer's field, they enrich the vegetation of the sea. We already have learned to harvest some of the ocean's crops, especially seaweed and kelp which hug the shore. We know of their abilities to collect chemically valuable vitamins and minerals and to reject salts. We can extract iodine from seaweed and process it into *algin* for use in cosmetics, textiles, paper, ink and drugs; we are studying the use of its organic components as food for yeasts and other protein-making microorganisms. We process kelp for cattle feed and fuel. Plankton is being studied as a potential source of amino acids and plant hormones.

Yet we know little about the ecology of this sea-life, how or why plants grow where they do, or how to plant or cultivate them.

Plankton, minute animal and vegetable life which form the base of the triangle of sea survival, present another example of neglected sealife ripe for research and eventual commerical development. So numerous they actually make the ocean "green," these mites have all the qualities of a well-rounded food product. They are high in protein and actually provide the main food of several species of whale.

Though rich in nutrients, they are unpleasant to the taste. Members of the *Kon-Tiki* expedition ate them with no ill effects, but only out of real necessity. However, with suitable processing plankton eventually could help solve the world's food distribution problem, since they are readily available in all the oceans of the world.

Abundant shallows of the sea

While man is beginning to think of the oceans as storehouses of food, he still competes with the predatory beasts of the sea, and his share is a small one. He has kept fish ponds for centuries, and recent emphasis on conservation in this country has led him to try stocking lakes and streams with fish and to destroy parasites in inland waters. Yet he chases the tuna and sardine as once he was satisfied with whatever he could catch on land.

Someday man will learn to select the best areas for fish, to breed and feed them and protect them for the harvest. Meanwhile we are experimenting with electric fishing techniques. In an electrical field, fish tend to swim toward a positive electrode, so the creation of a strong current beneath a ship directs them into a concentrated area, where they may be netted or scooped out with ease.

The oceans give up their treasures reluctantly, and often in unexpected ways. Plants and animals have mysterious ways of extracting chemicals and minerals from the brine. Copper is found in lobsters, vanadium in the sea cucumber, calcium in shells. In Texas, a profitable means has been found to extract magnesium from sea shells of Galveston Bay, which has grown into a full commercial operation.

An even stranger phenomenon came to light recently with the discovery of countless "nodules" on the sea bottom. These are small, brown-black stones which have been found to be rich in the ores of manganese, cobalt, nickel, and iron.

Although little is known of their origin, they seem to have "grown" around small-core objects like bits of volcanic glass or pumice or even shark's teeth. Nodules even may have been formed inside living organisms long since extinct.

We could recover them in quantity with an undersea dredge something like a vacuum cleaner which

Vice-Admiral Charles Bowers Momsen is well equipped to deal with the subject of oceanography; the better part of his 36-year naval career was spent with submarines and undersea warfare. He was appointed assistant operations chief for undersea warfare in 1948, and commanded the Pacific submarine fleet from 1951 to 1953. In 1954 he took over Joint Task Force Seven (overseas nuclear weapons tests) and served in this capacity until his retirement in 1955, when he was promoted to vice-admiral. He was instrumental in the development of the "Momsen lung" for submarine escapes, various rescue devices, and techniques of using helium-oxygen mixtures for deep-sea diving. Since his retirement he has been active as a consultant, writer, and lecturer in various facets of undersea life.

would sweep the ocean bottom and funnel the nodules to a mother ship on the surface. Artificial light sources and even television cameras could be employed in finding large concentrations. How they can be processed profitably and their precious minerals liberated, however, still is a problem.

Off the shore, and deeper

Beneath these abundant bottom lands lie additional sources of wealth barely touched. Mining sulfur in relatively shallow water has become a profitable industry, and it is estimated that our continental shelves could yield some 20-billion barrels of crude oil and 150-billion cubic feet of natural gas, using present practices. In all, 400-billion barrels of oil, about a third of all that remaining on earth, waits below the sea bed. Improved engineering skills soon will enable us to work in deep water and tap a great deal of this reserve.

Several large oil companies are exploring the bottom with seismic instruments. One large group, composed of Continental, Union, Superior, and Shell, has begun drilling in water more than a thousand feet deep. Stanford Research Institute has undertaken studies for the AEC on the possible applications of nuclear energy to oceanography, and one aspect to be considered is nuclear-powered deep-sea mining. Such an installation might be submerged and thus kept free from surface weather; the power source aboard could be used to process minerals while still at sea.

The preliminary stage of "Project Moho," in which a deep hole will be drilled beneath the ocean, through the earth's crust, and into the mantle, already has begun. While its stated purpose is pure research, ramifications in technological development and oceanography should prove invaluable to the petroleum industry and to others concerned with harvesting the wealth of the oceans.

Moho got its name from Andrija Mohorovicik, the Yugoslav who theorized from his studies of seismic waves that the crust beneath the ocean is thinner than under the continents. Here the boundary between crust and mantle, known as the Mohorovicik Discontinuity, is closer to the surface, and therefore accessible by deep drilling. In 1958 the American Miscellaneous Society was given formal status as the AMSOC Committee of the National Academy of Sciences, and funds provided for a study of the feasibility of drilling such a hole.

While the value to pure science of drilling a "mohole" is obvious, its byproducts in the form of increased technology would benefit private industry immensely. Cheaper, faster, and more effective drilling techniques will give the petroleum industry a great boost, and we can expect much information on the origin and size of oil deposits.

It even may be possible that a mohole can teach us how to tap the enormous heat supply of the earth's mantle and release it to the surface. Circulation of the water upwards would sweep with it rich bottom sediments and increase the food supply of fish.

Thorough engineering studies are now underway to modify drilling techniques for this new environment, provide instrumentation, and solve problems of corrosion and weight. Should Project Moho fail in its main purposes, its contribution to industry still would be considerable.

The unknown lower depths

If man knows little about the ocean waters and shallows so close to his own environment, his knowledge of the deeps is abysmal. Yet more than half the earth's area is covered with 10,000 feet of water or more.

Pressure presents the greatest obstacle to probing the deep ocean. Hence, explorations in this region

Recent discovery of countless nodules on the sea floor is considered a strange oceanographic phenomenon. These stones—rich in manganese, cobalt, nickel, and iron could be dredged by a submerged "vacuum cleaner" (perhaps similar to the vehicle pictured above left), with light sources to spot large clusters.

have been even more timid than those into space. The tiny bubbles of air man has designed to take him down are confining and clumsy, and every attempt to bring up a specimen of life has ended by having it explode. At 5,000 fathoms the pressure on each square inch of surface amounts to 13,350 pounds.

Oil ordinarily floats on water, but at these incredible pressures, water actually floats on the more-compressible oil. This gives rise to the theory that large pools of oil exist in the ocean depths, covered with tons of water and perhaps layers of sediment.

The great problem in deep-water research, of course, is getting down there. Present bathyscaphs can descend to 12,000 feet, giving access to about one-third of the ocean bottom. If structural problems can be solved to withstand pressures another mile down, we will be able to explore 95% of the area of the sea floor.

Reynolds Metals Co. has an aluminum research submarine under study which will descend to three miles, and the U.S. Naval Ordnance Test Station is making preliminary designs for a submarine to explore the bottom seven miles down. Submerged nuclear-powered research laboratories also are being studied for the AEC by Stanford Research Institute.

Part of the job of these undersea vehicles will be charting the topography of the ocean bottom for use in submarine navigation. Little is known about the lands under the oceans except that there is almost no erosion to wear away the mountains—a hazard to submarine shipping. Some progress is being made in mapping the bottom, but the task is immense. After all, there are still remote land areas which on maps are labeled "unknown," and more than three-fifths of the earth's surface is covered with water.

Tomorrow's 'low seas'

Russia already has an operational fleet of some 500 submarines, which puts an added emphasis on charting these waters. Scientists warn that our efforts to conquer the oceans must be re-doubled within the next 10 years or we will be lagging far behind. Aside from the military aspects of underwater transport, however, there is increasing hope that research may remedy the difficulties of present-day marine commerce.

Recent successes with nuclear submarines may pave the way to commercially successful undersea shipping of passengers and cargo, both liquid and dry, in the near future. The initial cost of a private nuclear fleet would be higher because of the power plant, but fuel savings would be great, it would be faster, and completely escape the delays and dangers of rough weather which hinder surface transportation.

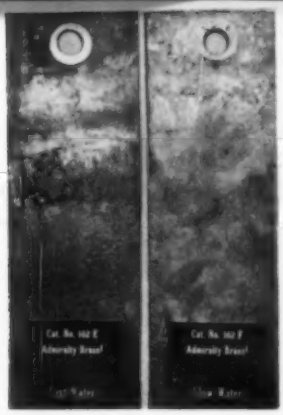
Trans-polar trade is another distinct advantage of undersea commerce; travel between Japan and Britain, for example, could be shortened by 5,000 miles by the use of submarine merchant ships.

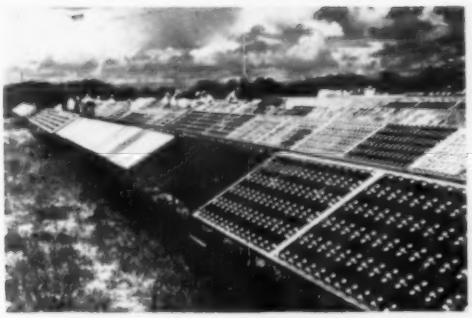
Our sky-probing is certainly more advanced than these quiet probings into the mysteries of the seas; we may reach the moon before we learn how deep the ocean is. Yet the commerical potential of the seas far outweighs that of space.

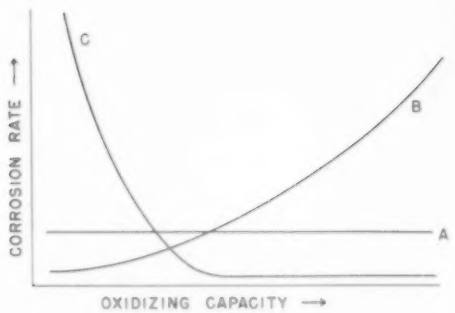
Willard Bascom, technical director of the AMSOC committee and long a spokesman for the commercial exploitation of ocean resources, indicts industry for the paucity of oceanographic research:

"Most businessmen are reluctant to spend enough money to make even the most tentative survey of business opportunities in the ocean. They expect to send a man to Scripps or Woods Hole for a day and have him come home with tales of great riches to be gained in a few months. Industry has not made even a minimum effort to learn about the problems and possible profits of the oceans.

"What the oceans need is a genuine old-fashioned entrepreneur." ■







by **Francis L. LaQue,** *vice-president, development & research division, The International Nickel Co. Inc.*

ENIGMATIC NATURE *of corrosion is shown in top photo, where brass in rapid-moving seawater (left) corrodes faster than same metal in stagnant seawater (right); exactly opposite behavior is found with stainless steel. Curves in chart show oxidizing capacity of a solution on corrosion rates of various metals, A, B, and C. An atmospheric test lot, above, is one of many at Inco's Kure Beach, N.C., facility. Pipe and pier corrosion experiments, left and bottom photos, are performed at nearby Harbor Island research station. Effects on corrosion of flow rates, fouling, cathodic protection, tidal changes, etc. are studied here.*

CORROSION, an Enigma

CORROSION, regarded simply as a nuisance by industrial management, is viewed paradoxically by those who work to prevent it. If the corrosion engineer were truly successful, he would be out of a job. And his ability to solve the problems of others does not keep him from having similar problems himself. For example, equipment used in the manufacture of corrosion-protective paint has been known to suffer corrosion damage itself.

The degree of experience one has with corrosion often determines his opinion of it. Neophytes may believe they understand the corrosion problems they have observed and feel capable of dealing with any similar future occurrences. "Experts" may suggest rational explanations for apparently anomolous behavior and thus

It is the rate of corrosion that's important—not whether

On a thermodynamic basis, one would hesitate to boil

Prior to becoming vice-president of Inco and manager of its development and research division in 1954, Francis L. LaQue headed the corrosion engineering section. Under his leadership, the company's widely known corrosion testing station at Kure Beach and Harbor Island, N.C., were established. LaQue, a native of Canada, is the new president of the American Society for Testing Materials, and vice-president of the Electrochemical Society, both for 1959-60. In 1949, he received the F. N. Speller Award in corrosion engineering of the National Association of Corrosion Engineers, of which he is past president.

view corrosion as a reasonably orderly phenomenon.

But corrosion engineers, like economists, know enough to provide plausible explanations of what has happened without being equally adept at predicting future occurrences.

Corrosion is difficult to predict with precision principally because the corrosion resistance of a material cannot be defined without reference to its environment. While it is possible to measure the properties that influence a metal's tendency to corrode, it is not practical to measure the characteristics that establish corrosivity of an environment. Even if such characteristics were measurable at any given moment, they would not remain constant and, in fact, would be changed at the corroding metal surface as a result of the corrosion process itself.

What's being corroded?

A further complication-within-a-complication is that it is not possible to describe the corrosivity of an environment without reference to what is being corroded. For example, there are many absolute bases for establishing that gold should be more resistant to corrosion than iron. Ordinarily this expectation is realized.

However, if the environment happens to be an aerated solution of sodium cyanide, gold will be attacked, and it is possible to dissolve gold in a sodium cyanide solution contained in a steel tank. Thus the corrosivity of sodium cyanide solutions is at one level when the metal involved is gold, and at a much lower level when the metal is iron.

In addition to the effects of changes in environment, such incidental factors as temperature and turbulence have powerful influences on corrosion. The influences are both direct and through side effects related to differences in temperature and velocity from point to point on the corroding metal surface. Similar complications emerge with respect to the concentration of gases (especially oxygen) that may be dissolved in a corroding liquid.

Impossible equations

All of this is a somewhat elaborate way to illustrate that while it is possible to predict the *tendency* for corrosion to occur on a thermodynamic basis, it is practically impossible to set up reliable equations for the *kinetics* of the same corrosion reactions.

From the practical point of view, it is the rate of corrosion that is important — not whether any corrosion at all may be anticipated. On a purely thermodynamic basis one would hesitate to use an aluminum kettle for boiling water.

Since it is impossible to calculate rates of corrosion from absolute data, the best estimate is likely to be based on past experience with the same combination of metal and environment. In the absence of past experience, it usually is necessary to observe behavior of the combination over a short period of time, and thereby predict what may happen during the desired life of the combination.

Acceleration . . .

It is important in the predicting process that results are obtained relatively quickly. One way to shorten the duration of a corrosion test is to make the corrosion conditions much more drastic than actually will be encountered. The assumption here is that a test solution 10 times more aggressive than the actual environment will bring about the same corrosion damage in one-tenth the time.

Many means have been used to achieve acceleration. These include increasing the concentration of what is assumed to be the most potent constituent of the corrosive solution, raising the temperature, changing the concentration of dissolved oxygen, etc.

Since such methods are likely to distort the normal corrosion reaction, it is not surprising that many accelerated corrosion tests have been unreliable. They provide a quick answer in lieu of an accurate one.

Simulation . . .

Another approach is to simulate corrosion. If the environment can be analyzed precisely enough to be reproduced accurately and completely (including minute concentrations that may have powerful effects on corrosion) and if the incidental conditions of exposure — such as temperature, velocity, aeration, etc. — can be measured or estimated quantitatively, it may be possible to approximate actual conditions in the laboratory. These requirements are met so rarely that while corrosion-rate tests under simulated conditions are usually more reliable than accelerated tests, they often fall short of what is desired.

Approximation . . .

A better procedure is to expose specimens in equipment already in operation under conditions of interest. Where a natural environment is involved, such as fresh water, seawater, or the atmosphere, specimens can be exposed easily. Yet, even here difficulties may arise in assuring that incidental conditions of exposure will encompass all the factors of turbulence, aeration, shelter, etc. that may be encountered in the proposed use.

Still another approach is to build a model or pilot plant and see what happens on a small scale so as to avoid the risk of unexpected difficulties with a full-size unit.

When observing normal rather than accelerated rates of corrosion, the short-time results must be extrapolated to predict long-time behavior. Even

he metal will corrode at all.

vater in an aluminum kettle.

when environmental conditions remain substantially constant (which is rarely the case), corrosion rates rarely remain constant.

Fortunately, rates usually decrease with time; often corrosion-product films form and become somewhat protective to the underlying metal. Consequently, tests of this sort tend to yield "safe" results.

Rules to corrode by

Many other examples can be cited to point out the enigmatic nature of corrosion:

- When using a protective coating to control galvanic corrosion, it is more important to coat the metal that isn't undergoing accelerated corrosion than to coat the one in which corrosion is being aggravated. If only the latter is coated, the situation is likely to be worsened by concentrating galvanic attack at imperfections in the coating.
- Where the mechanism of a corrosion reaction involves a galvanic-type cell based on differences in oxygen concentration from point to point, the accelerated attack occurs where the oxygen concentration is lowest.

This is in spite of the fact that under other circumstances the rate of corrosion increases with the concentration of dissolved oxygen (as with steel in water or copper in sulfuric acid). Thus aggravated attack frequently occurs inside crevices or under deposits where you might expect corrosion to be suppressed because of the limited access of corrosive media.

- With some metals (such as iron), oxygen or other oxidizing elements accelerate corrosion. With others (such as stainless steels), these same elements suppress attack.
- In many environments an increase in velocity or turbulence is damaging to some metals, but reduces attack on others. For example, in seawater some copper-base alloys that resist stagnant water very well are severely attacked when the water is in rapid motion — while exactly the opposite behavior is observed in stainless steels.

There are enough recorded observations in both anticipated and unexpected behavior to limit the number of surprising occurrences. The safest procedure is to recognize the complexity in what may appear to be a simple corrosion problem, rather than to ignore the possibility of trouble or to attempt short cuts. ■

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Cobalt Base	1800° F	SAC CHROMALLIZED cobalt base alloys are unattacked after 150 hours at 2200° F.
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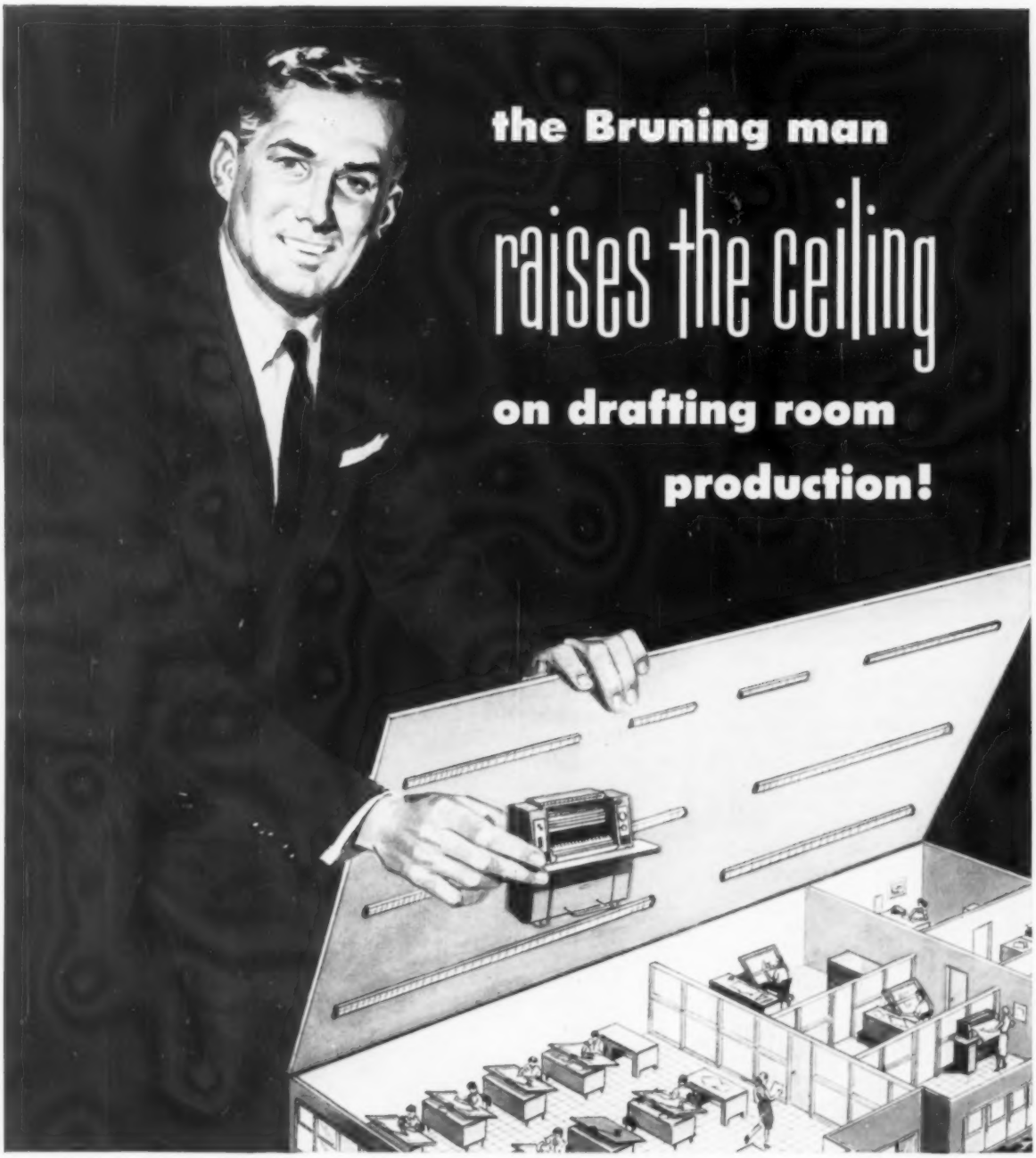

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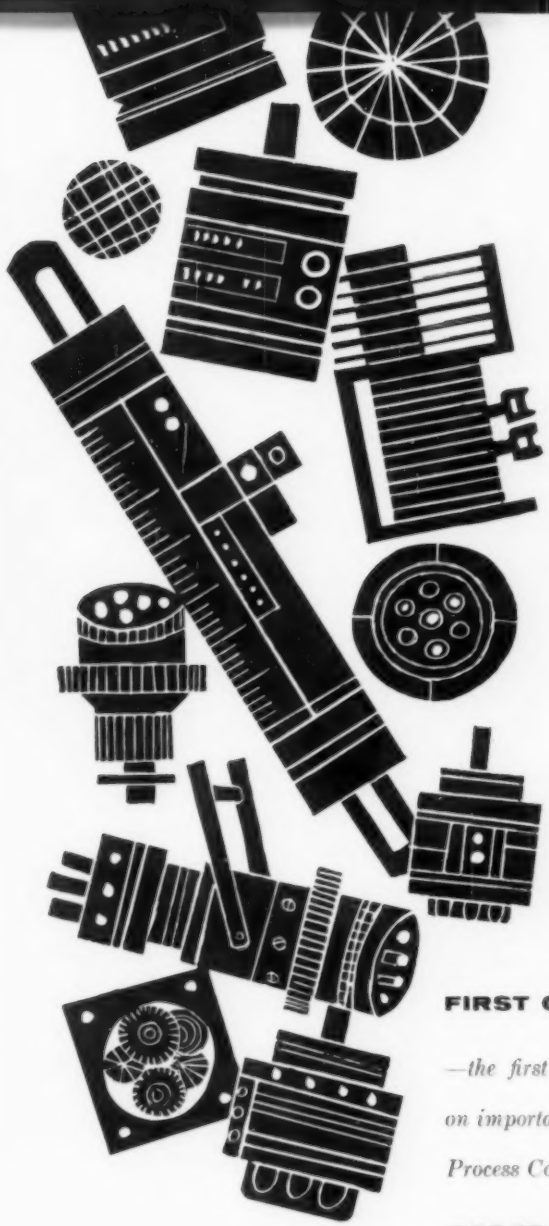

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RESEARCH
TRENDLETTER

Apr-May, 1960

Dear Sir:

The variety of metals available has tripled over the past 10 years. Many metals now can be refined to a degree of purity which formerly existed only in theory—99.999%. Some recent developments point the way toward better high-temperature coatings, new alloying techniques, and improved corrosion resistance.

A zinc coating for columbium has been developed at the U.S. Naval Research Lab that will protect it against oxidation at temperatures as high as 2200 F. The coating, which turns into a complex zinc-columbium oxide, is ductile and plastic at high temperatures, and "heals" itself if bare spots develop.

High-purity tungsten now can be plated easily on metal surfaces by using a Nat. Bureau of Standards vapor deposition process. Gaseous tungsten hexafluoride is reduced with hydrogen by passing it over the heated object to be plated. At temperatures over 300 C, tungsten is deposited on the hot surface, and the only other reaction product, hydrogen fluoride, passes out with the excess of hydrogen. Tungsten retains high structural strength over 2000 C.

A speedy single-step method of alloying refractory metals, developed by Alscope Explorations, is said to reduce processing costs up to one-third. The method makes alloys of refractory metals from base metals and low-cost oxides. The reducing metal plays a dual role; besides its reducing function, it also is the base metal for the alloy.

Carbide parts and tools to withstand high temperatures or corrosive media now can be produced in the shop. Chromalloy Corp.'s *Ferro-Tic S* is produced by powder metallurgy, embedding tiny crystals of hard titanium carbide in a relatively soft matrix of stainless steel. The composite retains properties of both its constituents: machinability and corrosion resistance of stainless steel, and the ultra-hardness of titanium carbide.

Corrosion of steel ballast tanks in ocean-going ships may be eliminated by putting in them new Alcoa long-lasting aluminum alloy sacrificial anodes, which gives cathodic protection.

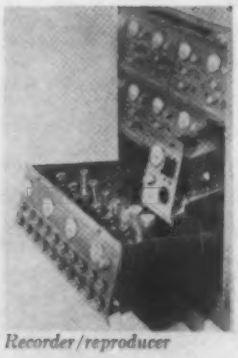
metallurgy

A Southern Research Inst. program to increase overall strength of stainless steel wire for towing aerial targets at distances of 25,000 to 40,000 feet employs electropolishing. Southern Researchers reasoned that by continuously tapering the wire they could provide a cross-sectional area proportional to strength requirements at every point along its length. Since no method exists for mechanically tapering wire, the tapering was achieved by electropolishing.

electronics

Eliminating circuits by control devices that use fluids instead of electricity and have no moving parts is being investigated by the Army's Diamond Ordnance Fuze Labs. The new control units consist of a block of metal or heavy plastic in which passageways have been made. They work by directing a weak stream of gas or liquid against the side of a strong stream. The weak stream, called the "control stream," displaces or redirects the "power stream" that does the real work. Units have been developed that can perform amplification, feedback, digital or analog computation, and normal mathematical and memory functions.

Corning Glass Works has developed a cathode ray bulb with 35,000 separate wire conductors embedded in a face plate only 3 x ¼ inches. Ca-



Recorder/reproducer

pable of printing 20,000 characters a second, it can be used to transmit by microwave or wire systems facsimiles of graphic and printed materials. Might revolutionize mail delivery! Sylvania processes the finished tube.

RCA's "nuvistor," thimble-size electron tube that takes up 1/16th the volume and consumes less than half the power of conventional triodes, is going into production. Made of ceramics, steel, molybdenum, and tungsten, the tube can withstand a high degree of shock and vibration. Applications range from data processing systems to medical diagnostic equipment.

◀ A new magnetic-tape system capable of recording and reproducing both analog and pulse signals has been developed by 3-M. The video band recorder/reproducer combines the capabilities of two machines in one.

A self-powered timing device said to be the world's most accurate portable time source, has been announced by Zenith. The *secondary time standard* can be used for "on-off" radio control of recording instruments or telemetering transmitters located in remote areas. As a control unit, it can turn on a switch at precise intervals.

A cryogenic gyroscope, by GE, may be useful in missile guidance and navigation systems for land vehicles and submarines. The rotor is niobium (*colombium*), which has a high critical field strength and remains superconductive up to 8 K. Liquid helium cools the system. Experiments using the lighter beryllium coated with niobium, are expected to lead to a practical "cryo-gyro" in three years.

"Cryovac" irradiated film

The film shrinks to a sanitary skin-tight fit for packaging perishable fruit, etc.

Scientists at Harvard claim they can analyze the grammatical structure of Russian sentences by computer. If so, the discovery is a significant advance in the struggle to translate Russian into English by machine. Syntax has been the stumbling block, preventing anything but rough, word-for-word translations. The Harvard system checks the inflected endings of Russian words to connect a word with its own modifiers. A "prediction pool" enables the machine to decide whether an adjective modifies the subject, for instance, by its position in the sentence. Once the subject of a sentence has appeared during the analysis, the prediction that the next word will be the subject is removed from the prediction pool. The machine proceeds through the sentence in this way, one word at a time. Each word determines the most probable grammatical form of the next word. At this point the machine checks to see whether all the requirements for a complete sentence have been met. If they have, it proceeds to the next sentence. If not, it goes back and tries various alternatives.

chemistry

◀ Irradiated plastic film—*electron-bombarded polyethylene, with a changed molecular structure*—has been developed by W. R. Grace & Co.'s Cryovac Div. The new material, for packaging, has high-shrink energy.

In the search for high-temperature lubricants, Battelle investigators have noted metal-free phthalocyanine as a promising material. It has remarkable thermal stability for an organic compound, and the fact that its molecule has a planar structure makes it of interest as a solid lubricant.

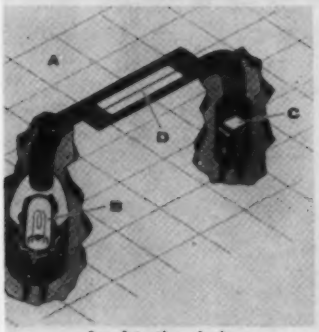
A process chromatograph that features substantially faster analysis and automatic programing of up to eight streams has been developed by Consolidated Electrodynamics Corp., now a subsidiary of Bell & Howell. Many analyses take less than 30 seconds with the new modular chromatograph, which consists of a small-volume pneumatically actuated sample valve, a small-bore packed column, and a fast-response detector.

Precision filter cartridge

◀ American Felt Co. has a new liquid filter cartridge that assures true micron precision in the process industries where controlled particle filtration is a problem.

Development of an improved tear gas—so effective that those who have tested it are rarely willing to try it twice—has been announced by the Army.

air and space



Ice detection device

◀ Ice on the wings can be detected easily by small-craft pilots in inclement weather with this device developed by Armour Research Foundation. Two translucent plastic rods, silvered for greater efficiency, are placed side-by-side on the wing (*A*). A light (*B*) projects through one; a photoelectric cell (*C*) monitors the other. When ice forms between the rods at (*D*), the light refracts through it to activate the cell and trigger an alarm. The thicker the ice, the more light refracted, and the greater the current produced by the photoelectric cell.

The impact point of a missile striking the ocean can be located by underwater detection systems developed by Bell Labs. The impact creates noise signals that are used to locate the spot where the missile hits water.

"Many millions of pounds" thrust are possible, says GE, with its "plug nozzle" rocket engine. Consisting of a ring of liquid-fuel power segments placed inside the cone at its widest, uppermost part, exhaust gas from these power segments pushes outward through the tip of the cone around a central "plug." GE says such an engine would be only about half the size of a conventional liquid-fuel rocket and probably wouldn't cost any more. Experimental engines have been producing thrust in the neighborhood of 20,000 lbs, but "several million-lb thrusts" are claimed feasible.

White algae for food

◀ Palatable white algae for use as food in space travel has been devised by Boeing biochemists. The white food (algae's color ordinarily is scum-green, and it tastes bitter) looks like flour and can be baked or prepared in paste form.

automotives

Automobile air-pollution research has been confined mostly to ways of cutting down on unburned hydrocarbons in exhaust gases. But now the breather pipe of the crankcase has been identified as a major emitter of hydrocarbons from gasoline. The Public Health Service is proposing legislation to make manditory a $2-pipe device, which returns these hydrocarbons to the engine for burning.

Electric autos may be on the streets this year. The *Kilowatt*, a Renault Dauphine converted to battery power; the *Starlite*, developed by Nu-Klea, a Michigan firm; and other products of small auto-makers are entering production. American Motors and Sonotone also are pursuing research on electric autos.

Do you have an invention? An opportunity to present it to manufacturers and investors at a National Inventions Conference, June 20-24, is offered by the Cleveland Engineering Society. Write: J. H. Gepfert at the society, 3100 Chester Ave., Cleveland 14.

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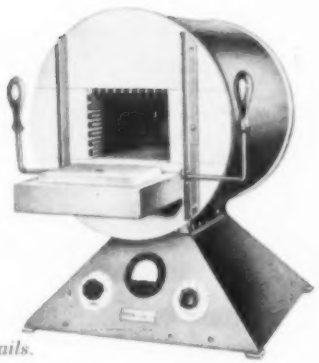

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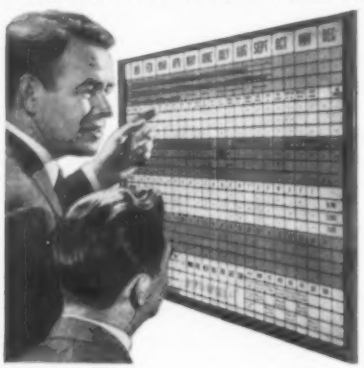

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